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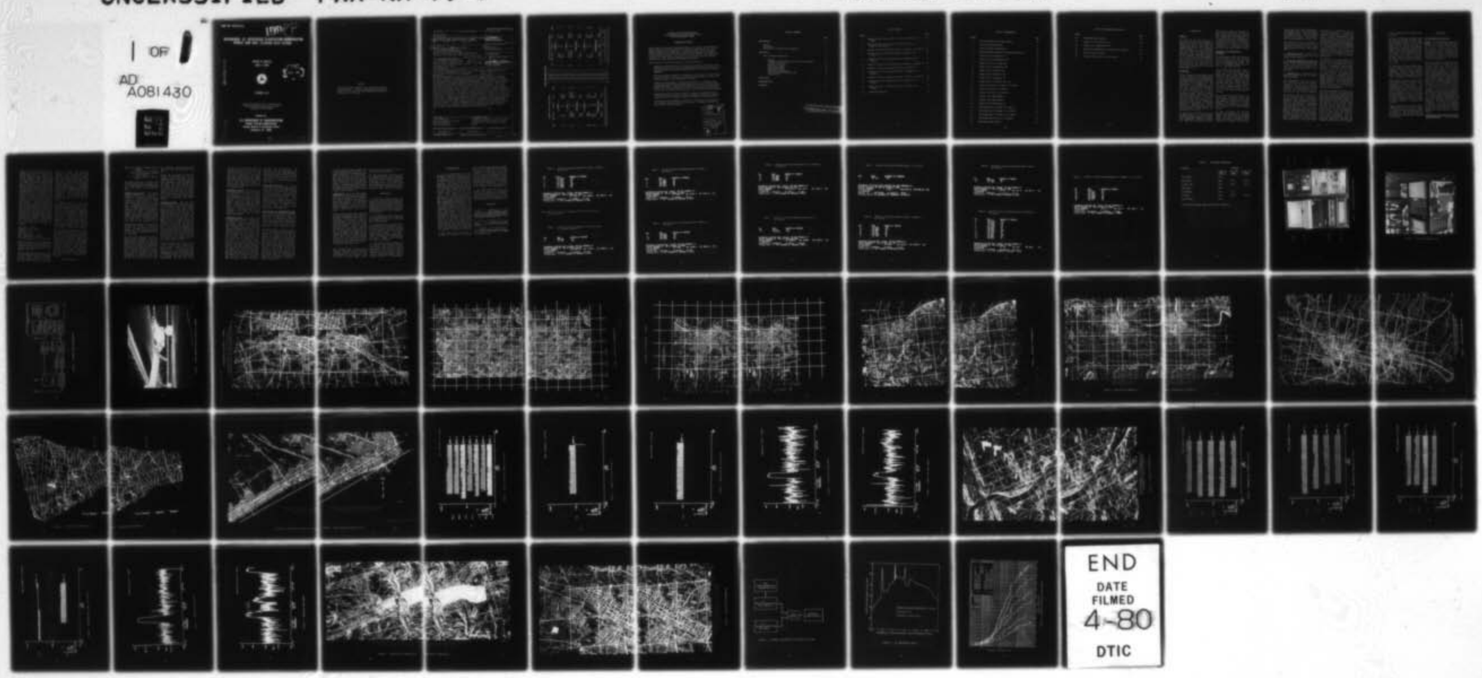

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Report No. FAA-RD-79-104

LEVEL II

MEASUREMENT OF INTERFERENCE-TO-NAVIGATION/COMMUNICATION AVIONICS FROM CABLE TELEVISION (CATV) SYSTEMS

EDWARD M. SAWTELLE
JAMES G. DONG

DECEMBER 1979

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16. Abstract

Airborne measurements of cable television (CATV) leakage were made at selected cities to compile a representative sampling of interference effects. Different altitudes were used in the flight-grid-type pattern. Ground measurements were also accomplished by the Federal Communications Commission (FCC) at the sites tested to determine any correlation between the ground and air measurements. The cities selected for discussion in this report were chosen to show various CATV effects detected by the data collection systems. A statistical analysis was performed on the data upon finding that direct airborne position correlation to strong ground leak points was not possible. The analysis provided the mean for each run of a grid and a comparison to determine if significant differences existed between runs. Where no significant differences were found, the condition was due to ambient noise exceeding signal level. Laboratory measurements were made to further confirm and define the interference of CATV leakage to VOR receivers. Recommendations include maximum signal level for CATV cable leakage that may be tolerated in the communication and navigation bands. A further recommendation was made that the CATV industry use frequencies in the navigation band which are separated from Federal Aviation Administration (FAA) navigation frequencies by 25 kilohertz.

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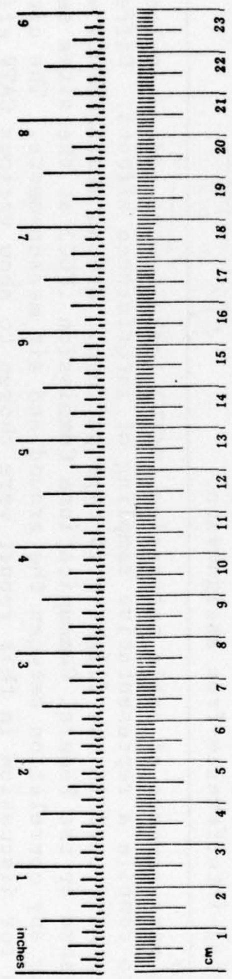
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

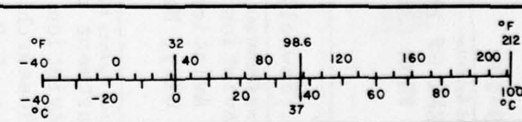
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



FEDERAL AVIATION ADMINISTRATION
SYSTEMS RESEARCH AND DEVELOPMENT SERVICE
SPECTRUM MANAGEMENT BRANCH

STATEMENT OF MISSION

The mission of the Spectrum Management Branch is to assist the Department of State, National Telecommunications and Information Administration, and the Federal Communications Commission in assuring the FAA's and the nation's aviation interests with sufficient protected electromagnetic telecommunications resources throughout the world and to provide for the safe conduct of aeronautical flight by fostering effective and efficient use of a natural resource--the electromagnetic radiofrequency spectrum.

This objective is achieved through the following services:

- Planning and defending the acquisition and retention of sufficient radio frequency spectrum to support the aeronautical interest of the nation, at home and abroad, and spectrum standardization for the world's aviation community.

- Providing research, analysis, engineering, and evaluation in the development of spectrum related policy, planning, and standards, criteria, measurement equipment, and measurement techniques.

- Conducting electromagnetic compatibility analyses to determine intra/intersystem viability and design parameters, to assure certification of adequate spectrum to support system operational use and projected growth patterns, to defend aeronautical services spectrum from encroachment by others, and to provide for the efficient use of the aeronautical spectrum.

- Developing automated frequency selection computer programs/routines to provide frequency planning, frequency assignment, and spectrum analysis capabilities in the spectrum supporting the National Airspace System.

- Providing spectrum management consultation, assistance, and guidance to all aviation interests, users, and providers of equipment and services, both national and international.

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INTRODUCTION

PURPOSE.

The purpose of this project is threefold: (1) make airborne measurements to determine field strength of interfering signals resulting from leakage radiation in cable television (CATV) systems; (2) in cooperation with the Federal Communications Commission (FCC) and CATV industry, provide airborne measurement support for the Institute for Telecommunication Sciences (ITS) airborne measurement system; and (3) provide information for the determination of the feasibility of predicting airborne CATV interference from ground measurements only.

BACKGROUND.

In the interest of preventing leakage in CATV systems from interfering with airborne receivers, Systems Research and Development Service (SRDS) has requested an investigation of CATV interference be accomplished. The importance of the problem was apparent from interference uncovered at Harrisburg, Pennsylvania. In April of 1976, aircraft using a newly assigned approach control frequency experienced CATV interference from the local CATV system. Four pilot carrier frequencies operating in different parts of the system produced audio heterodynes in airborne receivers. Laboratory test results showing the susceptibility of airborne receivers to CATV signals are documented in reference 1.

In April 1977, the FCC rejected the recommendations of the air transport industry through Aeronautical Radio, Inc. (ARINC)/Air Transport Association (ATA) and the Federal Aviation Administration (FAA) to prohibit the use of the aeronautical spectrum by CATV systems until adequate enforcement regulations were developed and the state-of-the-art of leakage monitoring became adequate. Consequently, information was required to develop procedures and criteria to minimize interference to aeronautical radio services from CATV signal leakage.

DESCRIPTION OF AIRBORNE TEST EQUIPMENT.

Two measurement systems were employed in the airborne tests. The Tektronix digital processing oscilloscope (DPO) and the ITS measurement system. The DPO is a broadband system while the ITS is a narrowband system.

The primary measurement system (figure 1) used in the CATV investigation was a DPO which employs TEK signal processing system (SPS) BASIC software. The software retains many of the standard features of the original Dartmouth BASIC. With the SPS BASIC high level support package, the user is able to write drivers with BASIC language commands used to control and handle data to and from the DPO system peripheral devices.

The storage medium selected for the system was a dual-drive floppy disk which employs flexible Mylar disks with magnetic surfaces as a recording medium. One diskette can store 256,000 bytes (8 bits each). Maximum data transfer rate is 27,500 bytes/second.

A scope, processor, and spectrum analyzer are contained in the mainframe. The processor has an analog signal interface, analog-to-digital (A/D) and digital-to-analog (D/A) converters, a memory to store digi-

tized waveforms and alphanumeric information, and a digital asynchronous parallel bus. The bus allows the digital devices to work independently or in concert. Device priority is established by a serial line.

The front panel of the processor is functionally divided into three sections: Display Source, Data Handling/Memory Location, and Program Call.

1. Display Sourte. These push buttons select the waveforms from memory and/or plug-ins.

2. Data Handling/Memory Location. These buttons control the Start and Stop of the waveform digitizing process and choose the memory location and which waveform is to be displayed.

3. Program Call. These are three buttons that indicate CPU BUSY, RESET, and CONT.

The remaining 13 push buttons are users definable and give remote capabilities over the external controller. These buttons allow the calling of special programs or subroutines. An overlay can be used to label buttons for special programs.

The spectrum analyzer is basically a tuned receiver with selectable frequency ranges, spans, intermediate frequency (IF) bandwidths, and a linear or log detector all integrated into the scope display. Additional characteristics include: fully calibrated displays, with 1 kilohertz (KHz) to 1800 megahertz (MHz) in one display, 30 Hz to 3 MHz resolution, 70 decibels (dB) on screen dynamic range, intermodulation (IM) distortion 70 dB below full screen, and -128 decibels per 1 milliwatt (dBm) sensitivity in combination with a tracking generator. The spectrum analyzer and generator provide dot marker functions. The generator sweep rates are controlled by the spectrum analyzer and the output level is controlled from the tracking generator. The output frequency of the generator is the same frequency as the analyzer at any instant of the sweep. The auxiliary output is used to drive the frequency counter which registers from 50 Hz to 550 MHz with a prescaler to give precise frequency measurements.

The controller is a minicomputer with a versatile instruction set and a memory of 28 thousand (K) 16-bit words. Front panel functions are RUN/HALT, RESTART, AND POWER. Indicator lights indicate the state of the processor, the bus, and the power supplies. All address/data functions are performed on the graphic terminal. A read-only memory (ROM) program in the controller allows extensive controller-terminal communication. The hardware and software interfaced to the controller allows program control of data acquisition and analysis.

The machine-language instruction set for the controller is practically identical to that of Digital Equipment Corporation (DEC) PDP-11/40. By removal of the small grant continuity cards, empty slots are available for the addition of DEC circuit boards coupling into the LS-11 bus. With the addition of a DEC ADV11-A A/D converter circuit board, 16 single-ended inputs can be accommodated. At each input a full scale range of 10.2 volts (V) bipolar (-5.12 V to + 5.12 V) can be tolerated. Only two inputs were required to join the instrument amplifiers receiving the automatic gain control (AGC) voltages

to the navigation and communications receivers.

Position information obtained from the inertial navigation system (INS) was supplied to both the ITS system and the DPO system. The serial output from the INS was converted to parallel by a circuit board fabricated in the laboratory to supply the proper input to the DEC DRV-11 circuit board. This additional interface unit was used to connect parallel-line transister-to-transistor logic (TTL) or diode-to-transistor logic (DTL) devices to the LSI-11 bus.

The ITS data recording system (figure 2) was comprised of the following modules: tape recorder, inertial navigation system interface/clock, fixed tuned receiver, tape recorder logic circuits, microcomputer, and a Texas Instrument (TI) terminal.

Data printed on the terminal were from samples placed in "bins" corresponding to signal levels. The equipment has a sampling rate of 5,000 samples per 25 seconds. Nine bins were devised with 10 dB difference between bins to cover the receiver range of -140 to -50 dBm. The histogram of the data collected was also recorded on magnetic tape. Detailed information on the ITS data collection system is available from the FCC.

Figure 3 depicts the airborne system configuration used for data collection. The antenna locations are shown in figure 4. The ITS equipment was connected to the forward antenna while the FAA equipment was connected to the other.

DISCUSSION

TEST PROCEDURES AND RESULTS.

GENERAL. Two independent measurement systems, one FCC the other FAA, were used in the airborne CATV interference tests. Both systems were operated by FAA personnel during the airborne tests. However, the printed data from the TI terminal and the magnetic tape recordings were released to the FCC for their analysis and interpretation.

The flight patterns employed were grid type flown at various altitudes (1,500, 5,000, and 10,000 ft) over selected cities that would provide representative samples of interference in CATV installations. Included in the investigation were new and old CATV installations that would provide a good comparison of systems with high signal leakage levels versus those with low signal leakage levels. Results of their interference measurements would be used to define the affected portions of service volumes after communication/navigation. Specific test locations included Atlantic City and Bridgeton, New Jersey; Harrisburg and Coatesville, Pennsylvania; Independence and St. Joseph, Missouri; Leavenworth and Lawrence, Kansas; Salisbury and Hagerstown, Maryland; and Arlington, Virginia. In addition, antenna calibration tests were accomplished for the FCC at the National Aviation Facilities Experimental Center (NAFEC) and Forbes Field in Topeka, Kansas.

BROADBAND FLIGHT TEST DATA COLLECTION AND ANALYSIS. The DPO system

used in data collection was programmed to record the image of the spectrum after every 77 intervals of signal maximums which was a convenient number to limit image usage of floppy disk storage. Analog data of receiver AGC and altimeter voltage were processed by the analog-to-digital converter and stored. The latitude and longitude of the INS was not recorded by either the FCC or FAA systems because of a malfunction in the INS bus, but the position at the start and finish of each run was manually recorded by observing the position displayed on the control display unit of the INS located in the cockpit. During flight data collection the reference frequency of the spectrum analyzer was corrected for drift periodically through use of the tracking generator which was provided a center frequency accuracy within 10 Hz. Maximum sensitivity of the spectrum analyzer under optimum conditions is -128 dBm. The dynamic range of the analyzer as used was 70 dB. Data were collected with the spectrum analyzer settings as follows:

Resolution - 30 kHz
Frequency Span - 50 kHz
Time/Div. - 5 ms
Phase Lock - ON
Input Attenuation - 0 dB
Ref. Signal Level - -60 dBm
Vertical Amplifier - 10 dB/Div.

With the exception of Harrisburg and Atlantic City, none of the CATV sites measured with the DPO system produced signals distinguishable above the ambient noise level.

Both the Harrisburg and Atlantic City cable systems have been in operation for more than 15 years, as compared to the systems measured in the mid-west which have been operating only 3 to 5 years. The Harrisburg system is in the process of being replaced. The following discussion will be limited to data on Atlantic City, Harrisburg, Coatesville, and Hagerstown. The FAA data and analysis are available from the NAFEC program manager for the remaining sites with the exception of Arlington where the DPO equipment experienced a failure due to vibration; however, testing was continued with the FCC equipment. Sites for which data analysis is not included in this report are shown in figures 5 through 11.

The maximum signal level data were recorded for each plot to show sequential variation in signal level. The data were also treated statistically. The plotting of data was done to allow a geographic comparison of runs to determine if nonlinear addition of a signal was occurring. The scales of these plots, with the exception of the dBm scale, have no relation to the data other than to assist in the plotting. Signal levels were corrected for a 10 dB loss between antenna and analyzer.

Where possible, a mean value for each run was computed and a reference distribution for 95 percent probability was determined for the runs listed in the tables. While the conclusions of the study were based mainly on the analysis of the signal variations, run means, and spectrum analyzer images, an analysis of variance (reference 2) was conducted on many of the data for the convenience of the reader. Included in the tables were the pooled variance and the F ratio calculated as follows:

$$F = (ST/V)/(SR/(N-V))$$

where: ST = between treatment sum of squares
V = degrees of freedom
SR = within treatment residual sum of squares
N = total number of observations

The group mean was calculated from the tables and equals the grand total of all observations (G) divided by the total number of observations (N).

ATLANTIC CITY FLIGHTS. The course flown at Atlantic City is shown in figure 12. In figure 13, runs 1, 3, 5, and 7 are plotted from flying course No. 1, while runs 2, 4, and 6 contain data from course No. 2. The start of each data plot is on the right. Geographically, the end (left side) of odd numbered runs correspond with the start of even numbered runs at the right of figures 13 through 15. The even numbered runs exhibit significant changes in level in the first half of the data and are at a lower level. The converse is true for the odd numbered runs.

Representative images of the spectrum analyzer are included in figures 16 and 17. As may be seen in these figures, the CATV radiated signal at 117.999 MHz is substantially above the noise level.

The statistical treatment of data is made for each altitude. The estimated mean is computed for each run (single pass across the city) and the data is then tested for significant difference in the means by the reference distribution and the F test. The only surprise in the data was in table 1 for run No. 1, which registered the highest mean even though the flightpath for the run was not over the city but along the beachfront. The grand mean (G/N) for the 1,500 foot data is -76.13 dBm.

Single runs were made at 5,000 and 10,000 feet, respectively, and a comparison between the two runs are shown in table 2. As shown, substantial difference exists between the two means. Run 8 was made at 5,000 feet while run 9 was at 10,000 feet. An appropriate decline in signal level was measured which would indicate that the level of signal from other sources was low and that there was no significant phase addition of individual CATV leakage sources.

HARRISBURG FLIGHTS. The flight grid of Harrisburg is shown in figure 18. In figure 19 the 1,500 foot data plots are those runs flown roughly parallel to the course of the river. Figure 20 depicts the data for runs flown perpendicular to the river. As expected, run 3 shows a higher level than the others in this set. The higher level is confirmed in table 3. However, run 9 in table 4 due to its location over the city was expected to be at a high level, but was not. Run 11, the run with the highest mean for the second set was flown perpendicular to the first set and was also the farthest from the center of the city. For plots of runs at 5,000 and 10,000 feet, see figures 21 and 22. Analysis of these runs are presented in tables 5 and 6.

The grand means for the runs at 1,500, 5,000, and 10,000 feet were -88.16, -91.86, and -82.98, respectively. The grand mean excludes run 17 in which the DPO apparently drifted off frequency from 117.999 MHz and had a calculated mean of -143 dBm. The single run 16 was approximately over the same course

as run 3 and, therefore, could be expected to be a high level. No explanation could be found as to why run 15, over the same course, did not also show a high mean. The representative spectrum analyzer images are presented in figures 23 and 24. The 117.999 MHz CATV signal is clearly seen above the noise level and occupies a significant portion of the swept spectrum.

COATESVILLE FLIGHTS. The flight grid of Coatesville is shown in figure 25. The data for Coatsville are representative of cities for which the 117.999 MHz CATV signal was not apparent in the spectrum analyzer image. No plots of data are shown since no signal rises above the noise level. Statistical treatment of the data is tabulated in tables 7 through 9. The grand mean for the signals is -94.6 dBm. This level represents the peak level of noise rather than signal.

HAGERSTOWN FLIGHTS. The flight grid of Hagerstown is shown in figure 26. In tables 10 and 11 there are no significant differences between the grand means of runs 1 to 13 and runs 21 to 27 which have means of -86.9 dBm and -86.8 dBm, respectively. The radiated signal was not seen on the spectrum analyzer even when the several dipoles were attached to the CATV system. An additional test was conducted at Hagerstown to determine if a heterodyne signal existed on the VOR receiver audio output when tuned to the CATV pilot carrier. The pilot carrier frequency was the same as the Harrisburg VOR, 112.5 MHz. The result was an audio beat frequency which was received on the VOR test receiver at 1,500 feet (460 meters (m)) and above to 10,000 feet (3,050 m). At times the heterodyne was strong enough to block the VOR Morse code identification. The Harrisburg VOR is approximately 50 nautical miles (nmi) from Hagerstown. Subsequent tests by the FCC confirmed that the CATV was responsible for the heterodyne. No other effects to the VOR system were observed during the flight test.

GRAND MEANS COMPARISON. The resolution over which the maximum desired signal was selected was approximately 20 kHz and is representative of a VOR receiver resolution. The grand means for cities/airports was found to be significantly different. This difference is largely due to the ambient noise signals appearing in the measurement resolution and not to the difference in CATV signal measured. Table 12 presents these grand means for comparison.

LABORATORY VOR INTERFERENCE TEST. The frequency interference measurements were accomplished using the equipment configuration shown in figure 27. A minimum very high frequency omnirange station (VOR) signal of 5 μV was selected for the laboratory test which is the signal level employed in FAA airborne checks.

The signal levels that will cause a "flag" indication (nonoperational status of the receiver) are shown in figure 28. Signals as low as -109 dBm and -106 dBm will cause a flag at ±30 Hz and ±9,960 Hz, respectively, from the tuned receiver frequency. These effects are the result of zero beats occurring between the interfering signal with normal carrier and subcarrier from the VOR. At all test levels, it was found that if the interfering signal was modulated, it was audible when the receiver audio output was monitored with earphones. Additional laboratory analysis is found in reference 1.

It can be inferred that leakage from a CATV system radiating at a frequency employed by a VOR station can cause the receiver to be unreliable. This is particularly true, if the aircraft is over the on-frequency CATV leakage area and the VOR receiver is tuned to a distant VOR station. The field intensity available from a distant VOR station can be obtained from figure 29 which was extracted from reference 3.

UNCERTAINTIES. Due to an INS program variation, no INS data were recorded. The loss of INS position information had little effect on the value of other data recorded. The principal DPO problem appears to be the equipments inability to deal with the adjacent ambient noise level which varies considerably from city to city.

The tests for Arlington were modified so that the ambient noise could be measured separately from the on-frequency interfering signals. Unfortunately, a failure in the DPO prevented recording with the broadband equipment. Also an error resulted from a computer program problem that caused every value of the 11th sample to appear to be several dB higher than those preceding and following. The effect was not great since it was a small constant added to all runs and did not affect the between run comparison and it resulted in less than 1 dB effect on the mean at the -90 dB level.

The communications receivers were tuned to 118.0 MHz, and the AGC was recorded. However, due to the high nonlinearity of the response at the low level of desired signal, little information was gained from the receivers' AGC recording.

The VOR navigation receivers were not operated because the frequency selected was not within the VOR frequency band. The frequency, 118.0 MHz, used in the FCC fixed tuned receiver was selected to avoid FM interference observed when the receiver was tuned at 108 MHz.

CONCLUSIONS

1. Flight-test data indicate that television cable systems, except for Atlantic City and the old (reportedly being replaced) Harrisburg systems, radiated at a level equal to or below the ambient noise level and would not interfere with the avionic communication receivers.

2. The measured level of noise varies approximately 20 dB based on the flight-test data at 1,500 feet above cities tested.

3. Laboratory tests indicate that VOR receivers will experience interference at levels as low as -109 dBm to -106 dBm at 10 KHz off frequency from the VOR carrier. The interference may be either in the audio, flag, or bearing, or a combination of the three. Flight tests confirmed the audio interference.

4. There was correlation between air and ground CATV leakage measurements which indicates that ground measurements are adequate, but in congested areas where numerous man-made structures impose restrictions on ground measurements, limited airborne testing is a requirement.

RECOMMENDATIONS

1. It is recommended that the combined effect of radiation from all cable television leakage sources be maintained below the sensitivity of VHF air-ground communication receivers. In areas of excessively high environmental noise (i.e., at or above the receiver threshold, typically -100 dBm), radiation from CATV systems should not increase the ambient noise level by more than 3 dB. These conditions could be satisfied by airborne measurements made with a receiver equivalent in RF and IF frequency responses to the RTCA minimum performance standard for VHF communications receivers. The receiving antenna should be of standard commercial grade with approximately 0 dB gain over isotropic and located on the aircraft per manufacturer's instructions. Measurements should be made during periods of minimum environmental noise at an altitude not to exceed 1,500 feet AGL. The CATV system should be monitored continuously on the ground so that new leaks which could increase the interfering signal level in the airspace can be detected and repaired as quickly as possible.

2. The CATV industry should be requested to separate all radiation in the avionic navigation band (108.0 MHz to 117.95 MHz) 25 KHz from FAA navigation frequencies. The CATV carriers in the band should be required to have a frequency stability of $\underline{+}5$ KHz (approximately 0.004 percent) percent to insure required separation allowing for drift between FAA and CATV frequencies. The radiated signal should not exceed the levels listed in recommendation 1.

3. The CATV data base for the avionic band should be incorporated into the FAA communications frequency selection program so as to automatically detect contravention of the 60 nmi separation of cochannel usage.

REFERENCES

1. Harr, T., Haakinson, E., and Murahata, S., Electromagnetic Compatibility of Simulated CATV Signals and Aircraft Navigation Receivers, O.T. Report 74-39, June 1974.

2. Box, G. E., Hunter, W. G., and Hunter, J. S., Statistics For Experimenters, John Wiley & Sons, 1978.

3. Del Balzo, J. M. and Willey, V. E., VORTAC Relative Field Intensity, Final Report, FAA Task No. 115-905-27, November 1961.

TABLE 1. ANALYSIS OF DATA FOR ATLANTIC CITY RUNS 1 THROUGH 7, AT 1,500 FT

RUN	MEAN	DEGREES OF FREEDOM
1	-71.5758	109
2	-78.4631	76
3	-77.9723	98
4	-76.5772	76
5	-75.4439	109
6	-77.7959	87
7	-76.5192	87

REFERENCE DISTRIBUTION= 1.31683 FOR 95% PROBABILITY
POOLED VARIANCE OF ONE ALTITUDE= 41.3985
SUM OF SQUARES: ST= 3361.5 SD= 29980.8 SR= 26619.3 SA=
3.76159E+06
SUM OF Y^2: 3.79158E+06 G=-49409.3 N= 649
F RATIO WITH 6, 643 DEGREES OF FREEDOM= 13.5331

Note: SD is the total sum of squares of deviation and SA is the correction factor

TABLE 2. ANALYSIS OF DATA FOR ATLANTIC CITY RUNS 8 AND 9, AT 5,000 AND 10,000 FT

RUN	MEAN	DEGREES OF FREEDOM
8	-80.602	87
9	-91.748	109

REFERENCE DISTRIBUTION= 3.62105 FOR 95% PROBABILITY
POOLED VARIANCE OF ONE ALTITUDE= 334.49
SUM OF SQUARES: ST= 6073.63 SD= 71968.2 SR= 65894.6 SA=
1.49158E+06
SUM OF Y^2: 1.56355E+06 G=-17185.3 N= 198
F RATIO WITH 1, 197 DEGREES OF FREEDOM= 18.1578

TABLE 3. ANALYSIS OF DATA FOR HARRISBURG RUNS 1 THROUGH 5, AT 1,500 FT

RUN	MEAN	DEGREES OF FREEDOM
1	-91.7581	76
2	-91.6349	98
3	-83.0559	98
4	-88.4113	98
5	-87.7351	76

REFERENCE DISTRIBUTION= .952916 FOR 95% PROBABILITY
POOLED VARIANCE OF ONE ALTITUDE= 21.0045
SUM OF SQUARES: ST= 4765.5 SD= 14190.3 SR= 9424.75 SA=
3.52431E+06
SUM OF Y^2: 3.53850E+06 G=-39068.1 N= 451
F RATIO WITH 4, 447 DEGREES OF FREEDOM= 56.5049

TABLE 4. ANALYSIS OF DATA FOR HARRISBURG RUNS 8 THROUGH 11, AT 1,500 FT

RUN	MEAN	DEGREES OF FREEDOM
8	-86.5647	98
9	-92.3935	76
10	-88.8246	54
11	-81.1674	43

REFERENCE DISTRIBUTION= 1.20707 FOR 95% PROBABILITY
POOLED VARIANCE OF ONE ALTITUDE= 25.6958
SUM OF SQUARES: ST= 3769 SD= 10758.3 SR= 6989.25 SA=
2.11921E+06
SUM OF Y^2: 2.12997E+06 G=-24140.9 N= 275
F RATIO WITH 3, 272 DEGREES OF FREEDOM= 48.8926

TABLE 5. ANALYSIS OF DATA FOR HARRISBURG RUNS 12 THROUGH 15, AT 5,000 FT

RUN	MEAN	DEGREES OF FREEDOM
12	-93.2657	87
13	-90.7022	131
14	-92.0395	87
15	-92.0051	87

REFERENCE DISTRIBUTION= 1.23217 FOR 95% PROBABILITY
POOLED VARIANCE OF ONE ALTITUDE= 38.7309
SUM OF SQUARES: ST= 355.75 SD= 15577 SR= 15221.3 SA=
3.34145E+06
SUM OF Y^2: 3.35702E+06 G=-36376 N= 396
F RATIO WITH 3, 393 DEGREES OF FREEDOM= 3.06172

TABLE 6. ANALYSIS OF DATA FOR HARRISBURG RUNS 16 AND 17, AT 10,000 FT

RUN	MEAN	DEGREES OF FREEDOM
16	-82.98	98
17	-143.682	131

REFERENCE DISTRIBUTION= 1.66116 FOR 95% PROBABILITY
POOLED VARIANCE OF ONE ALTITUDE= 80.5935
SUM OF SQUARES: ST= 208448 SD= 226985 SR= 18536.5 SA=
3.19830E+06
SUM OF Y^2: 3.42528E+06 G=-27181 N= 231
F RATIO WITH 1, 230 DEGREES OF FREEDOM= 2586.41

TABLE 7. ANALYSIS OF DATA FOR COATESVILLE RUN 1, AT 1,500 FT

RUN	MEAN	DEGREES OF FREEDOM
1	-99.614	142

REFERENCE DISTRIBUTION=0.582356 FOR 95% PROBABILITY
POOLED VARIANCE OF ONE ALTITUDE=12.5358
SUM OF SQUARES: ST=0 SD=1792.63 SR=1792.63 SA=
1.41898E+06
SUM OF Y^2: 1.42077E+06 G=-14244.8 N=143
F RATIO WITH 0,143 DEGREES OF FREEDOM=1.35724E+37

TABLE 8. ANALYSIS OF DATA FOR COATESVILLE RUNS 11 THROUGH 17, AT 1,500 FT

RUN	MEAN	DEGREES OF FREEDOM
11	-102.327	153
12	-94.2395	153
13	-94.2003	87
14	-92.671	76
15	-92.7945	98
16	-92.9183	76
17	-94.1386	65

REFERENCE DISTRIBUTION= 1.45624 FOR 95% PROBABILITY
POOLED VARIANCE OF ONE ALTITUDE= 54.7102
SUM OF SQUARES: ST= 9545 SD= 48334.5 SR= 38789.5 SA=
6.51497E+06
SUM OF Y^2: 6.56330E+06 G=-68251 N= 715
F RATIO WITH 6, 709 DEGREES OF FREEDOM= 29.0775

TABLE 9. ANALYSIS OF DATA FOR COATESVILLE RUNS 17 AND 18, AT 1,500 FT

RUN	MEAN	DEGREES OF FREEDOM
17	-94.1386	65
18	-92.7486	54

REFERENCE DISTRIBUTION= .550484 FOR 95% PROBABILITY
POOLED VARIANCE OF ONE ALTITUDE= 4.63958
SUM OF SQUARES: ST= 58 SD= 614.75 SR= 556.75 SA=
1.05796E+06
SUM OF Y^2: 1.05858E+06 G=-11314.3 N= 121
F RATIO WITH 1, 120 DEGREES OF FREEDOM= 12.5011

TABLE 10. ANALYSIS OF DATA FOR HAGERSTOWN RUNS 1 THROUGH 13, AT 1,500 FT

RUN	MEAN	DEGREES OF FREEDOM
1	-86.9336	54
2	-86.3646	120
3	-87.0148	76
4	-87.0332	98
5	-86.7776	76
6	-86.8892	87
7	-86.3166	43
8	-86.9922	109
9	-87.1478	87
10	-87.0072	76
11	-87.024	120
12	-86.8981	87
13	-86.8423	76

REFERENCE DISTRIBUTION= .358783 FOR 95% PROBABILITY
POOLED VARIANCE OF ONE ALTITUDE= 2.77297
SUM OF SQUARES: ST= 59 SD= 3137 SR= 3078 SA=
8.46833E+06
SUM OF Y^2: 8.47146E+06 G=-97475.4 N= 1122
F RATIO WITH 12, 1110 DEGREES OF FREEDOM= 1.77307

TABLE 11. ANALYSIS OF DATA FOR HAGERSTOWN RUNS 21 THROUGH 27, AT 1,500 FT

RUN	MEAN	DEGREES OF FREEDOM
21	-86.6	76
22	-86.9258	87
23	-87.153	76
24	-86.7535	76
25	-86.7338	65
26	-86.7897	87
27	-86.717	54

REFERENCE DISTRIBUTION= .39154 FOR 95% PROBABILITY
POOLED VARIANCE OF ONE ALTITUDE= 2.86686
SUM OF SQUARES: ST= 15 SD= 1511.5 SR= 1496.5 SA=
3.97972E+06
SUM OF Y^2: 3.98123E+06 G=-45839.8 N= 528
F RATIO WITH 6, 522 DEGREES OF FREEDOM= .872835

TABLE 12. GRAND MEANS COMPARIONS

Location	Altitude		
	1,500 feet (dBm)	5,000 feet (dBm)	10,000 feet (dBm)
Coatesville	-94.6		
Harrisburg	-88.2	-91.9	-83.0
Atlantic City	-76.1	-80.6	-91.7
Hagerstown	-86.9		
Independence	-73.2	-73.7	
Salisbury	-85.4	-85.8	-69.0
*Forbes Field	-94.8		

*Forbes Field, Topeka, Kansas FCC Antenna Calibration

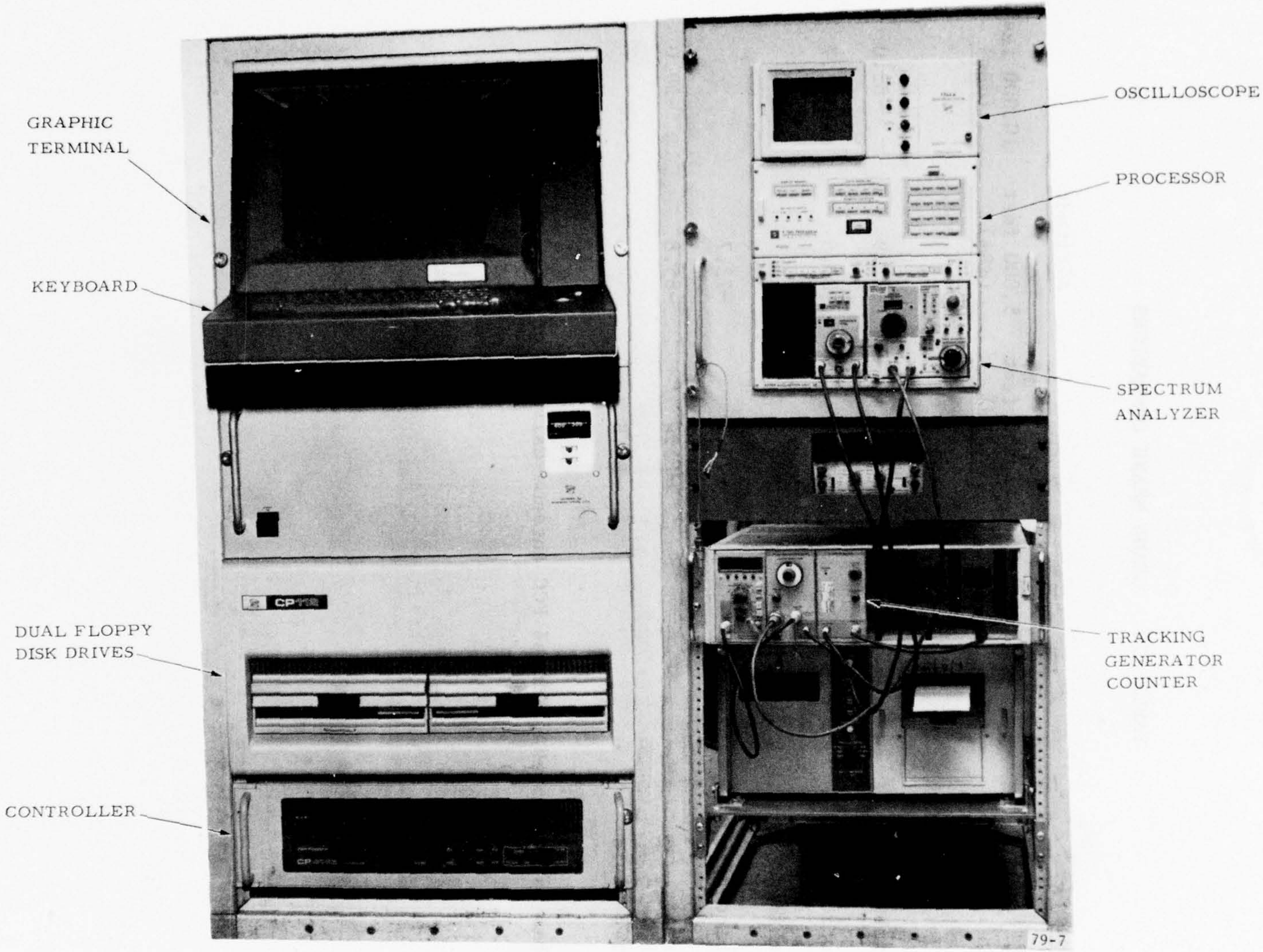


FIGURE 1. DATA PROCESSING OSCILLOSCOPE SYSTEM

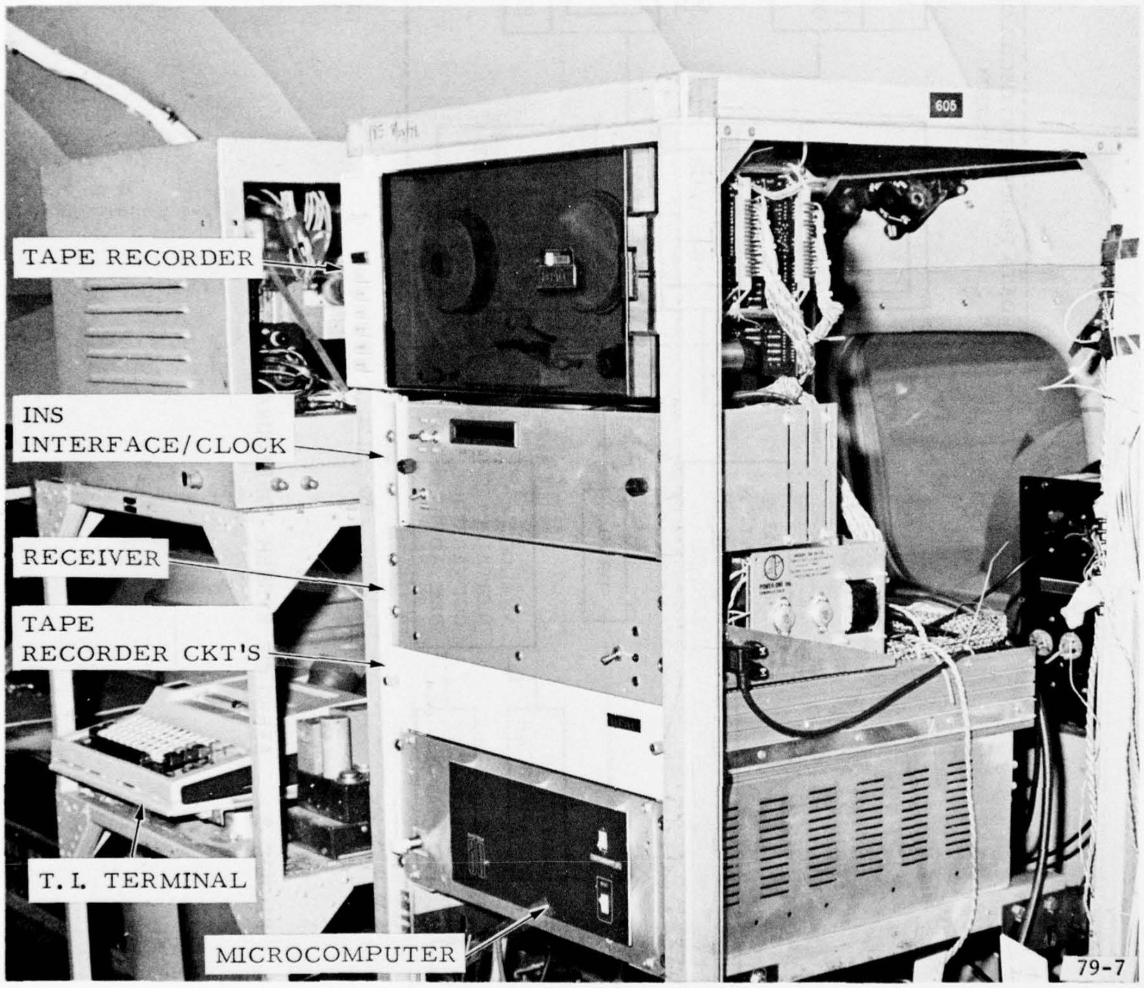


FIGURE 2.   ITS DATA RECORDING SYSTEM

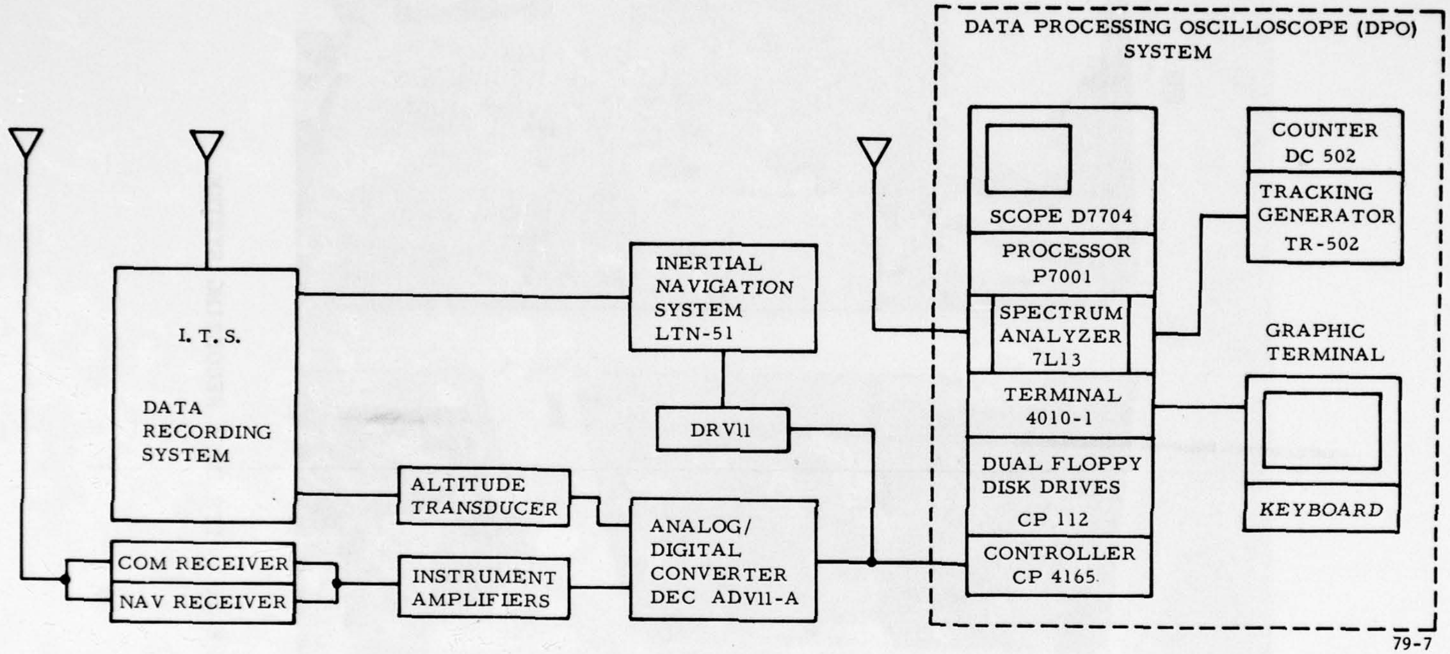


FIGURE 3. AIRBORNE SYSTEM CONFIGURATION

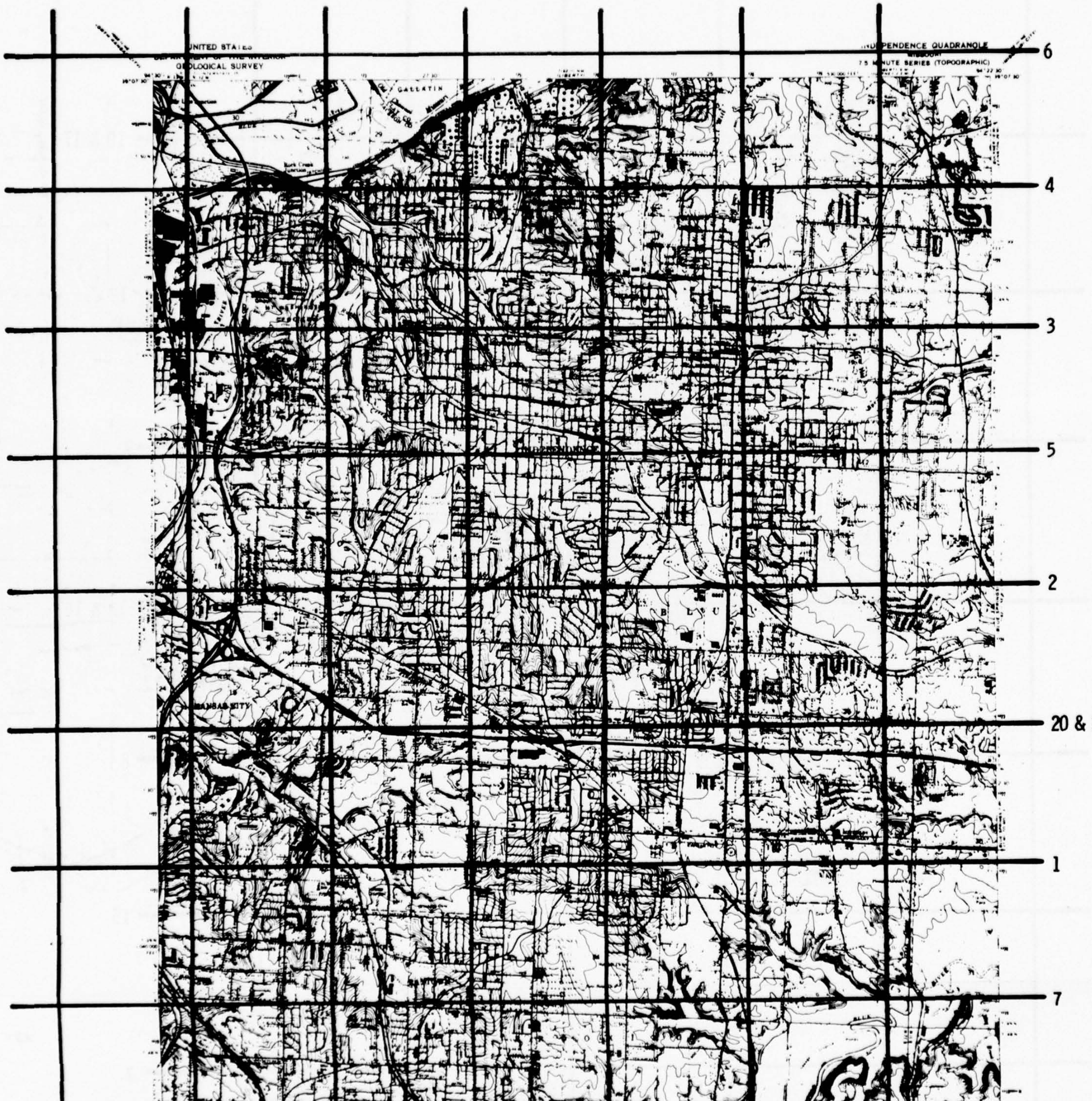
79-7

FIGURE 4.   NAV/COM ANTENNA LOCATION ON CONVAIR 580 AIRCRAFT

FIGURE 5. FLIGHT GRID OF BRIDGETON, NJ


BRIDGETON
East Lake
Raceway
Sunset Lake
Bridgeton Junction
CENTRAL
RAILROAD
TRUE
11
12
13

1 2



UNITED STATES
GEOLOGICAL SURVEY
INDEPENDENCE QUADRANGLE
7.5 MINUTE SERIES (TOPOGRAPHIC)
GALLATIN
KANSAS CITY
SCALE 1:24 000
6
4
3
5
2
20 & 21
1
7
8

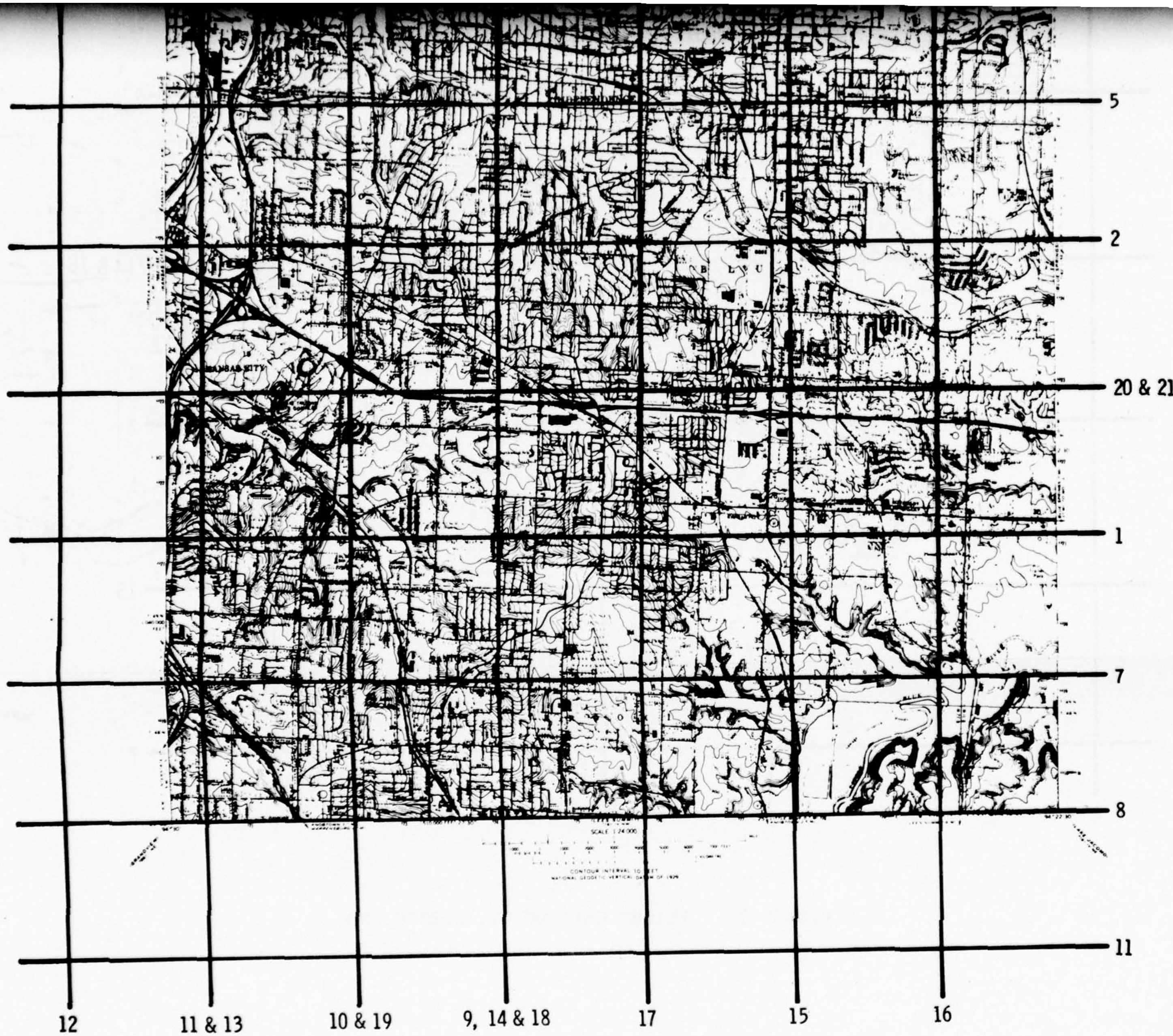


FIGURE 6. FLIGHT GRID OF INDEPENDENCE, MO

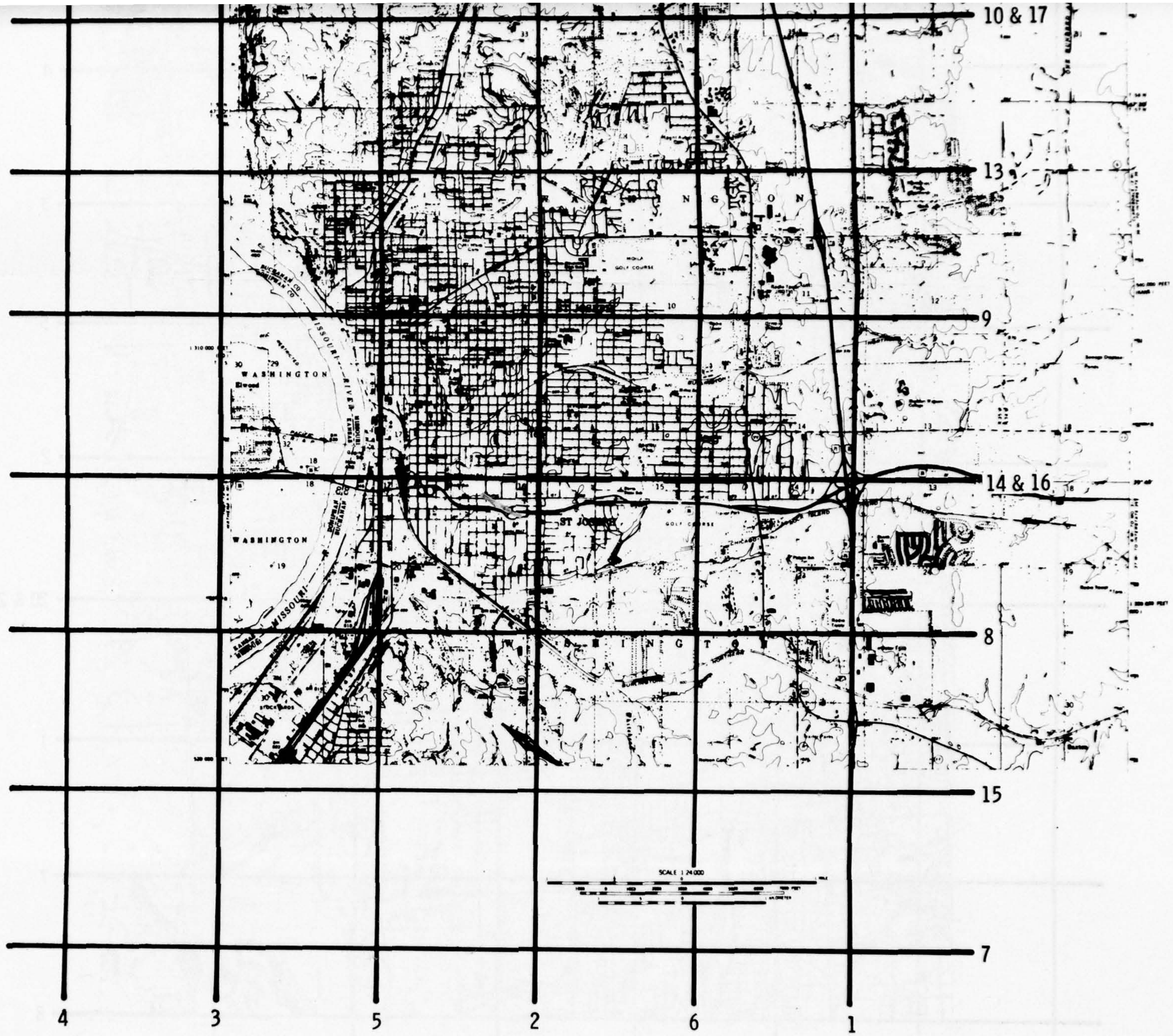
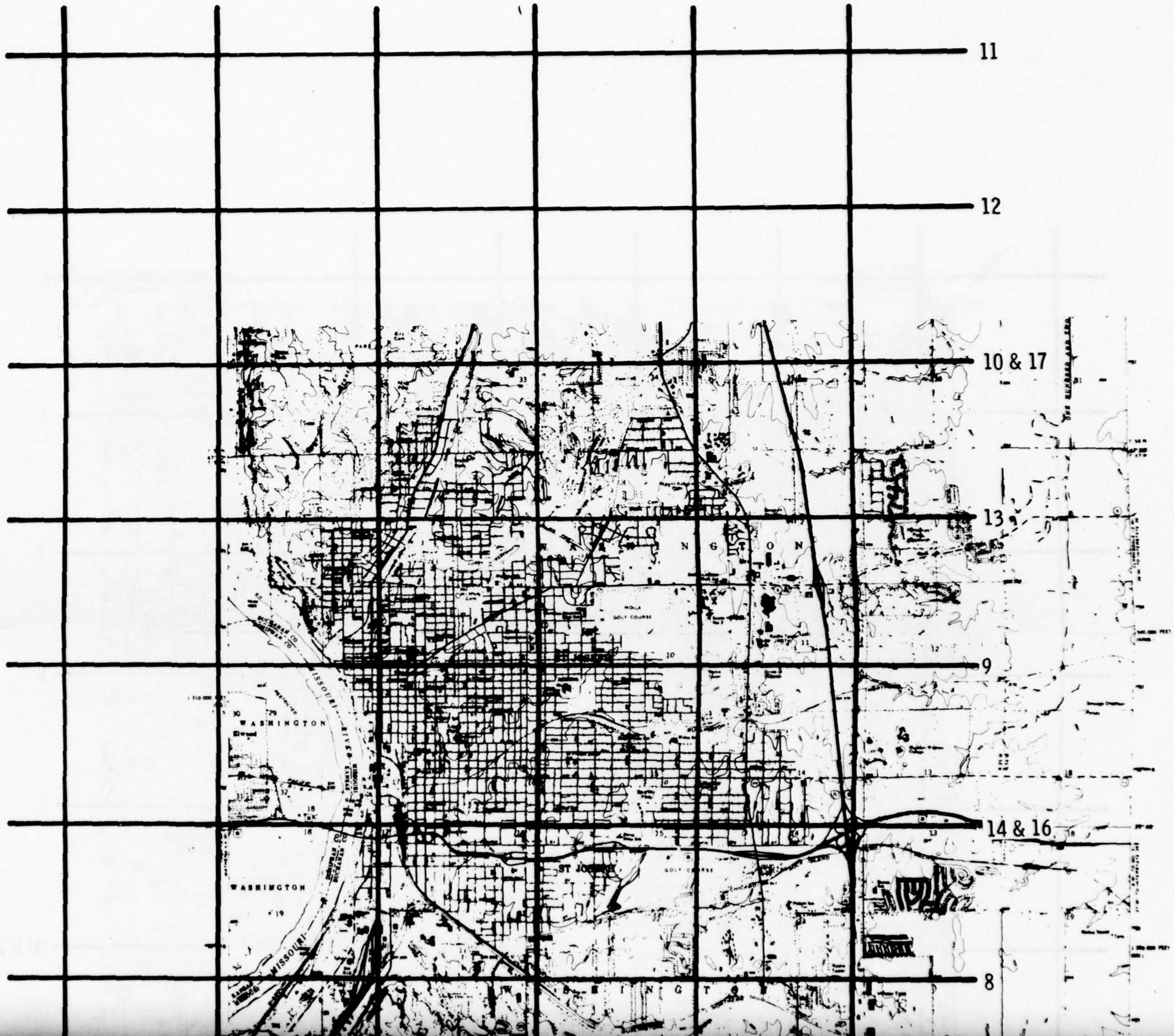


FIGURE 7. FLIGHT GRID OF ST. JOSEPH, MO



11
12
10 & 17
13
9
14 & 16
8
WASHINGTON
MISSOURI
ST JOSEPH
GOLF COURSE

2


6
7 & 11
9, 12 & 16
8
10
4
1 & 14
3, 13 & 15
5
2
MISSOURI
RIVER
MISSOURI
KANSAS
FEDERAL PENITENTI
MILITARY RESERVATION
Stigers Island
SCALE 1:24 000

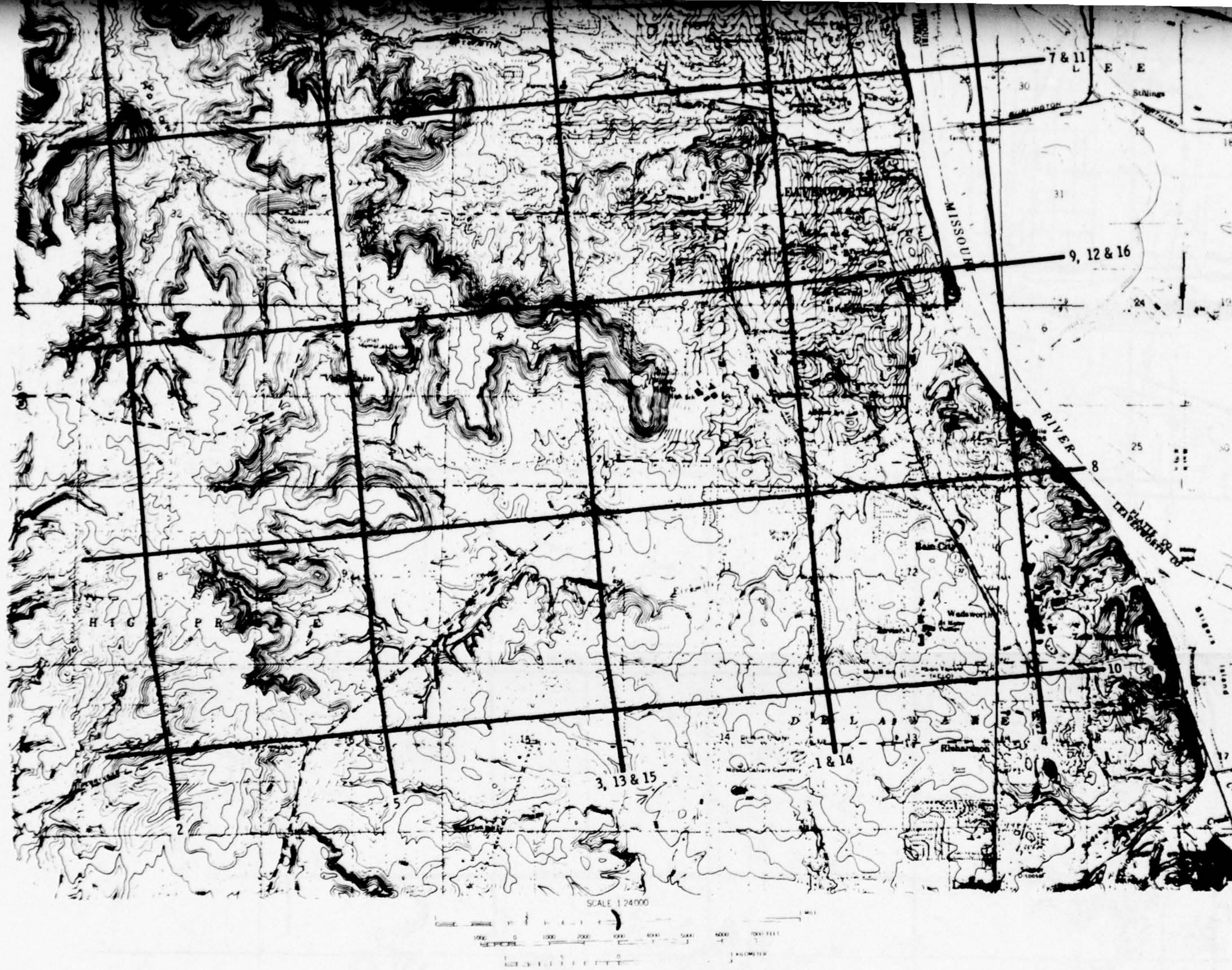


FIGURE 8.   FLIGHT GRID OF LEAVENWORTH, KS

2

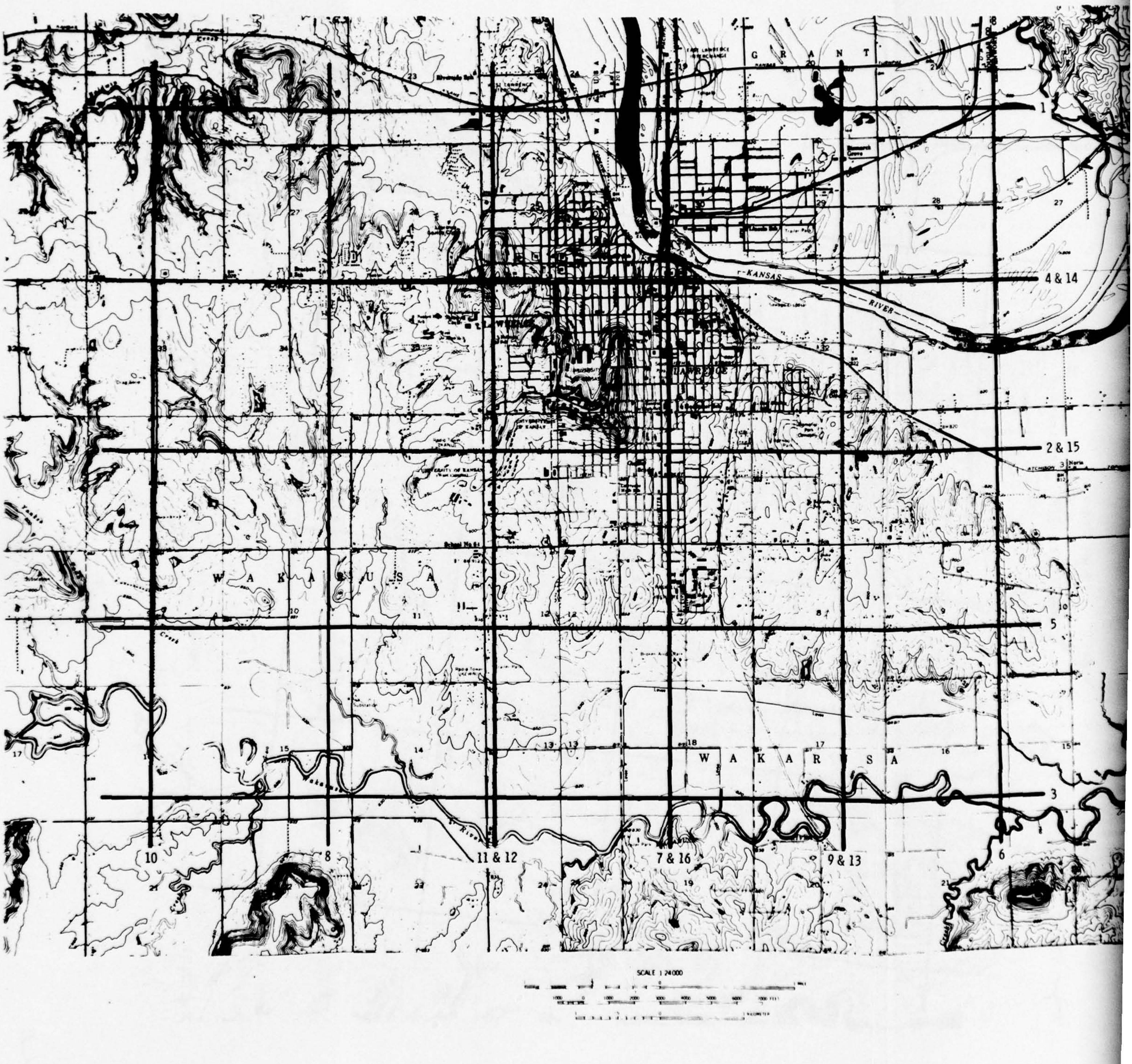
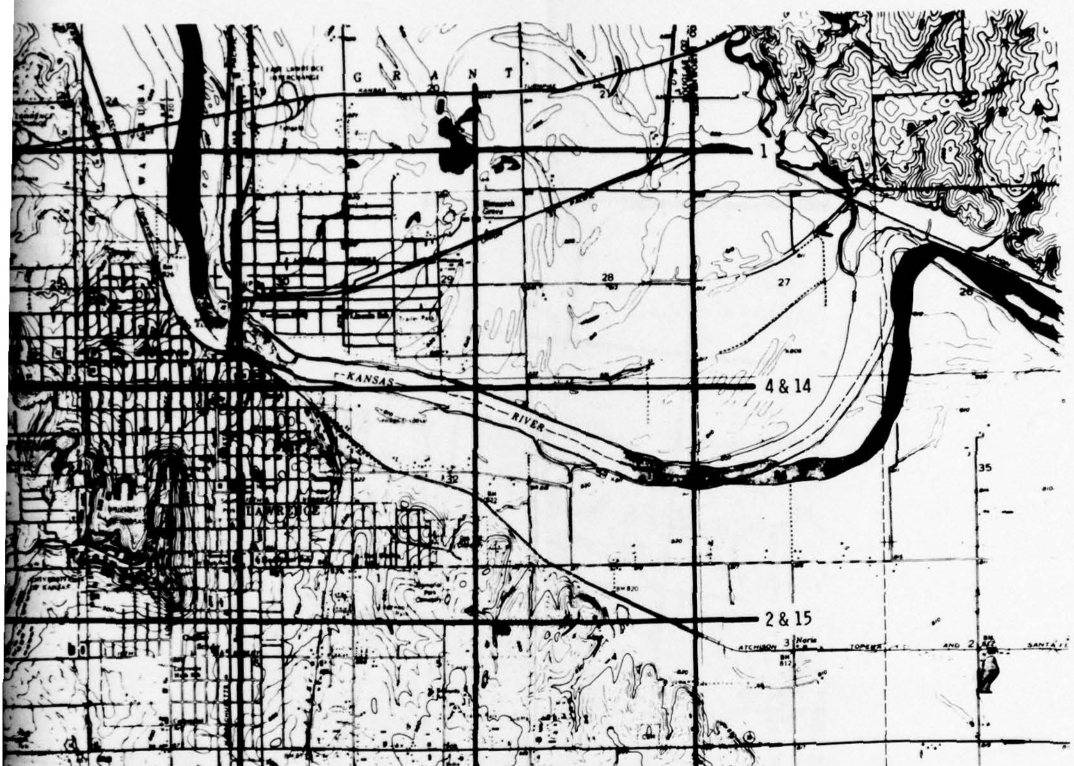


FIGURE 9. FLIGHT GRID OF LAWRENCE, KS

2



E 9. FLIGHT GRID OF LAWRENCE, KS

2


TRUE
SALISBURY NO 9
SALISBURY
Salisbury Airport
Brewington
Middle
Branch
RADIO TOWER
Johnson Pond
State Game Farm
Wicomico
Park Lake
Beaverdam
Schumaker Pond
Wicomico Memorial Park
Bitter Head Point
Owl Point
Williams Point
Harbor Point
WICOMICO RIVER
Nancy Point
BALTIMORE AND EASTERN
CHARITY
1
2 & 11
3, 10 & 12
4
6 & 15
7
8 & 14
9
13

79-7

FIGURE 10. FLIGHT GRID OF SALISBURY, MD

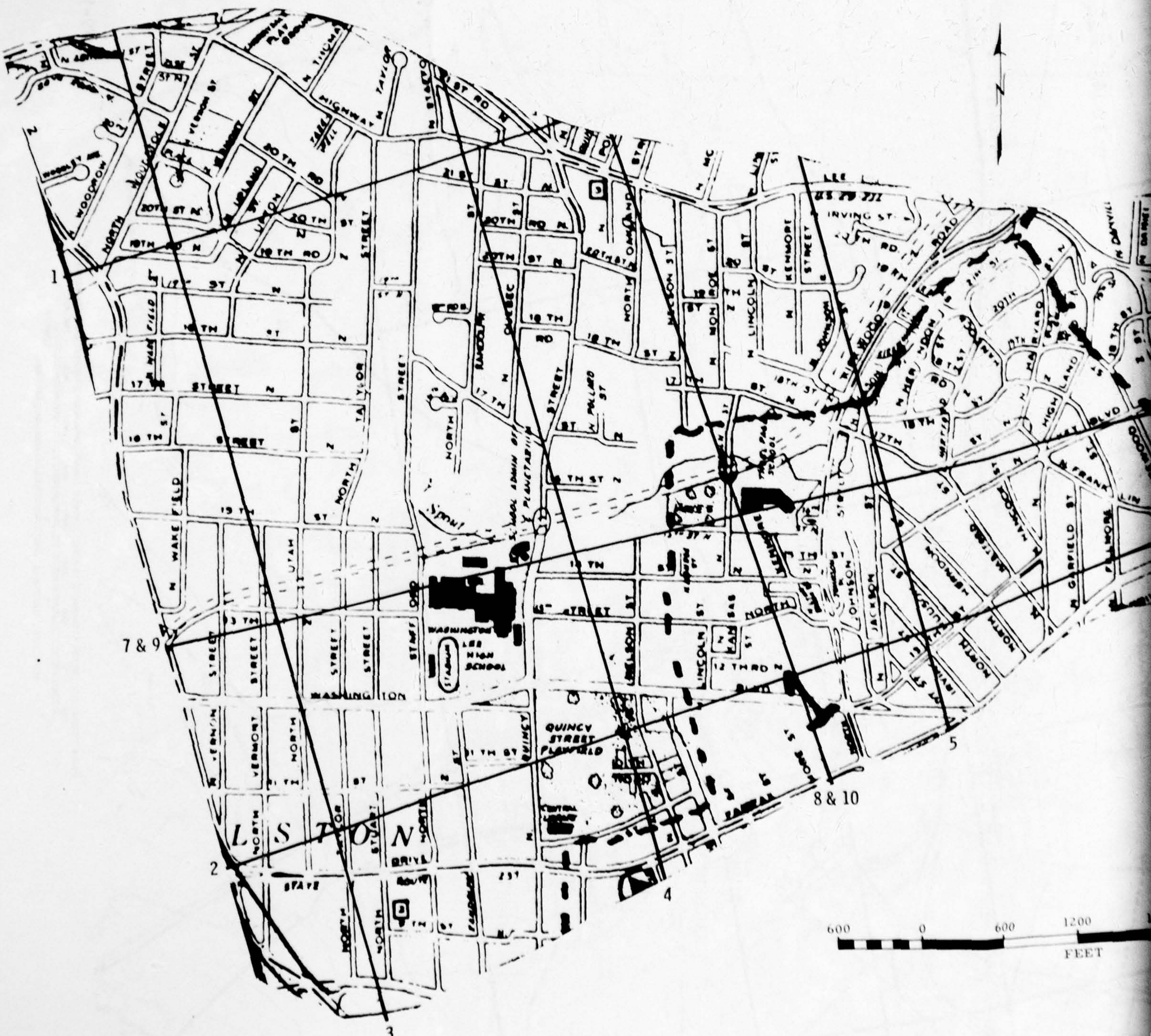


FIGURE 11. FLIGHT GRID OF ARLINGTON, VA

E 11. FLIGHT GRID OF ARLINGTON, VA

2

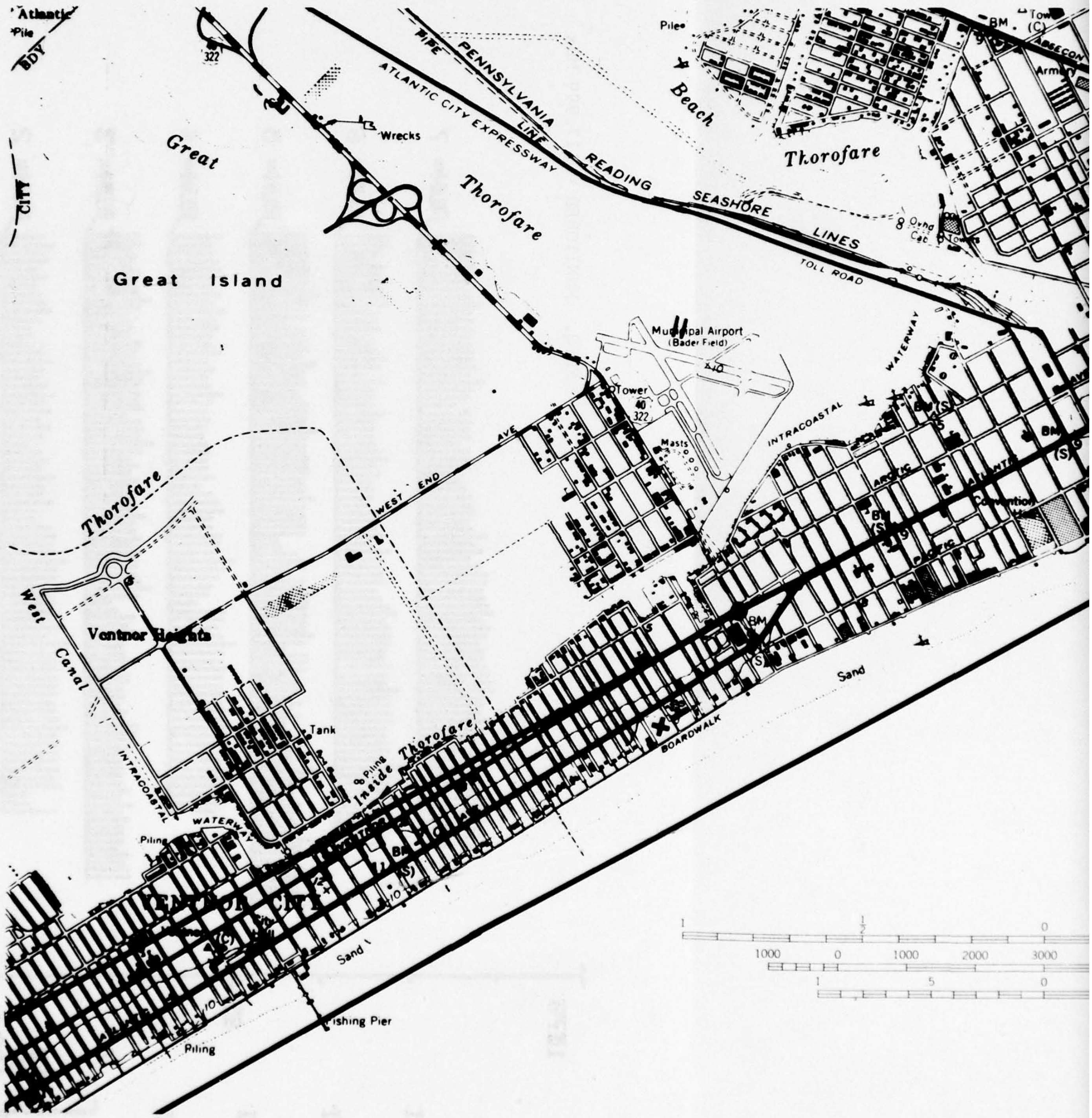


FIGURE 12. FLIGHT COURSE OF ATLANTIC CITY,

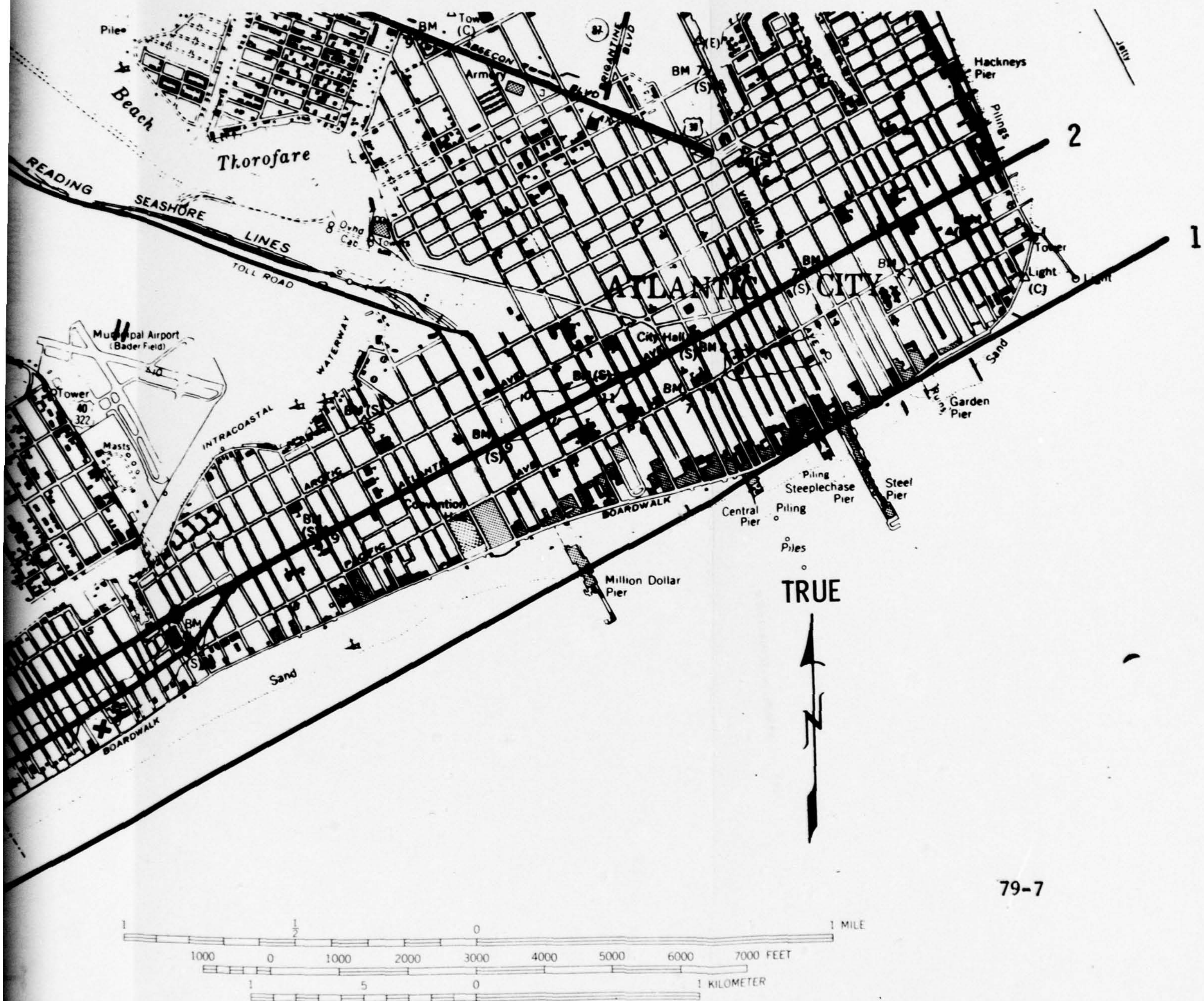


FIGURE 12. FLIGHT COURSE OF ATLANTIC CITY, NJ

2

FREQ. MONITORED = 117.999 MHz

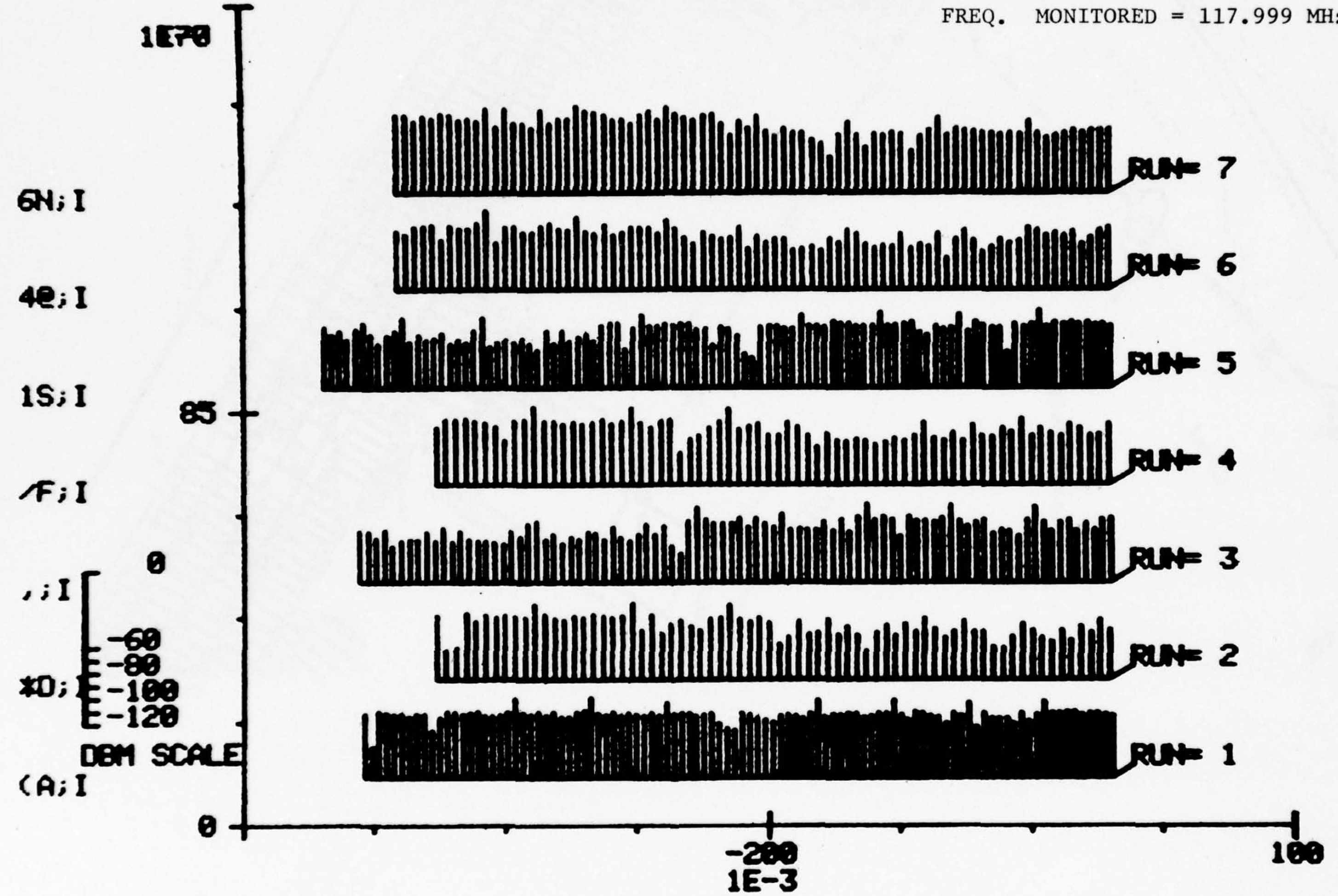


FIGURE 13. ATLANTIC CITY RUNS 1 THROUGH 7 AT 1,500 FT

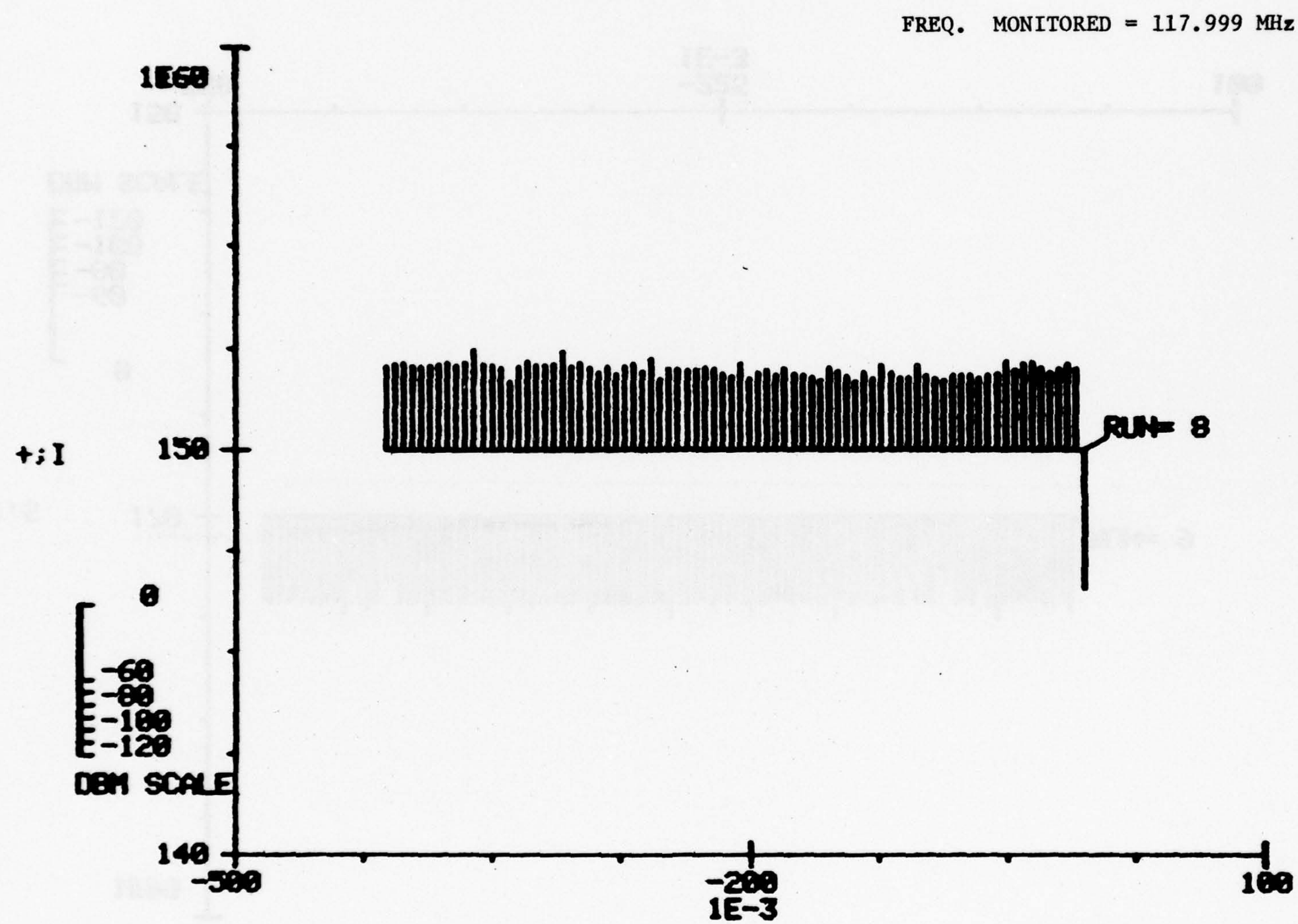


FIGURE 14. ATLANTIC CITY RUN 8 AT 5,000 FT

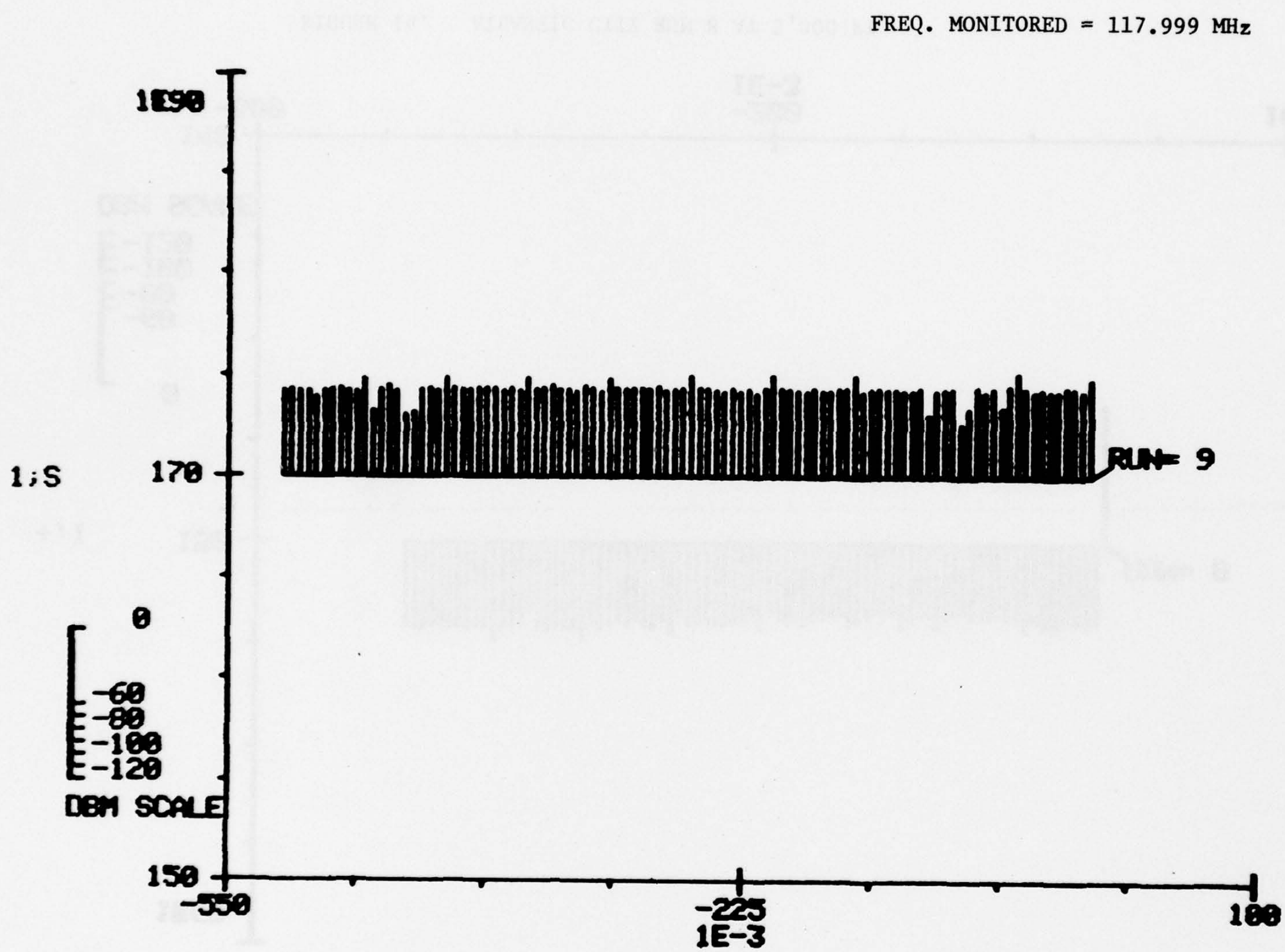


FIGURE 15. ATLANTIC CITY RUN 9 AT 10,000 FT

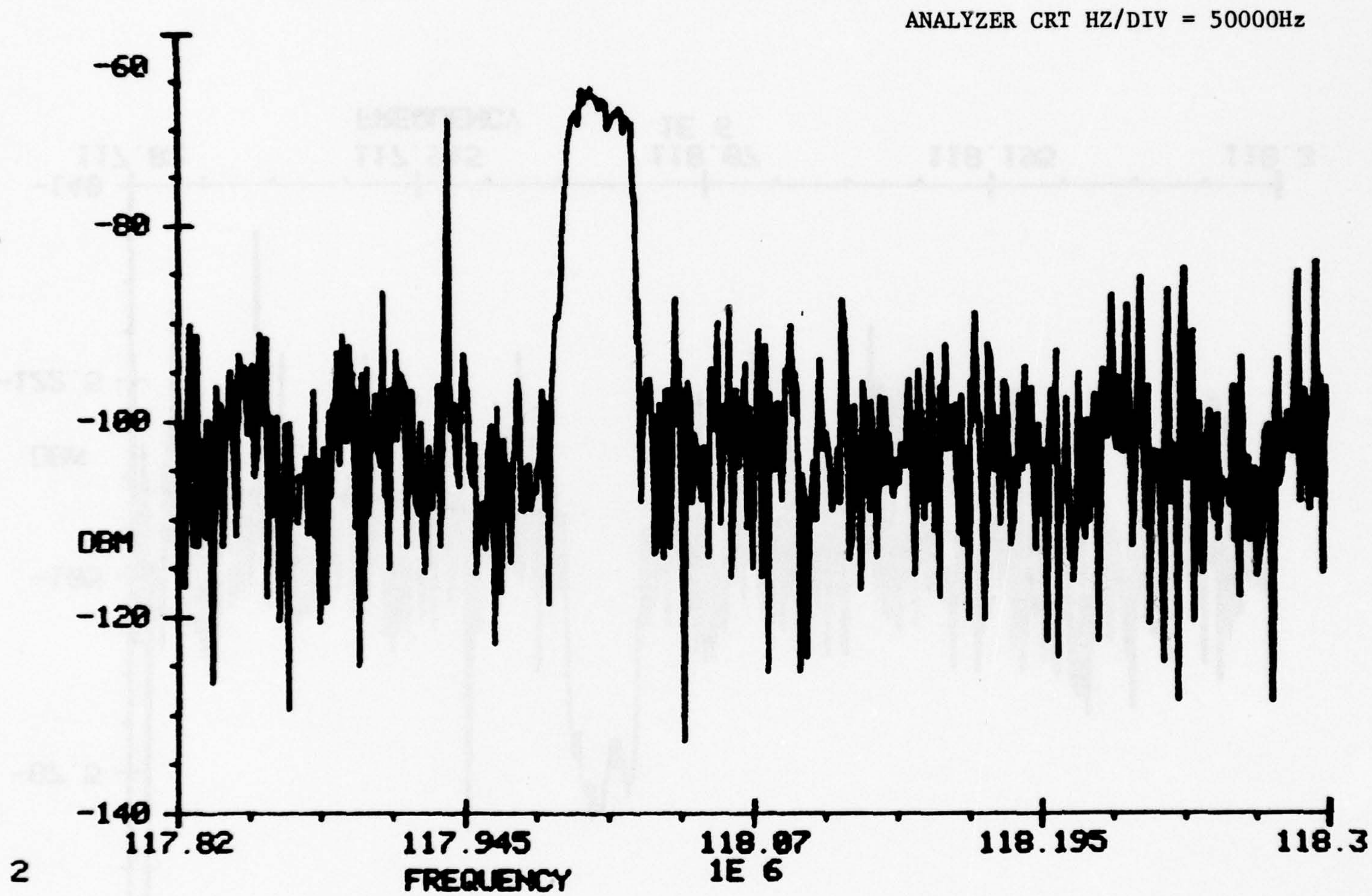


FIGURE 16. ATLANTIC CITY IMAGE NUMBER 1

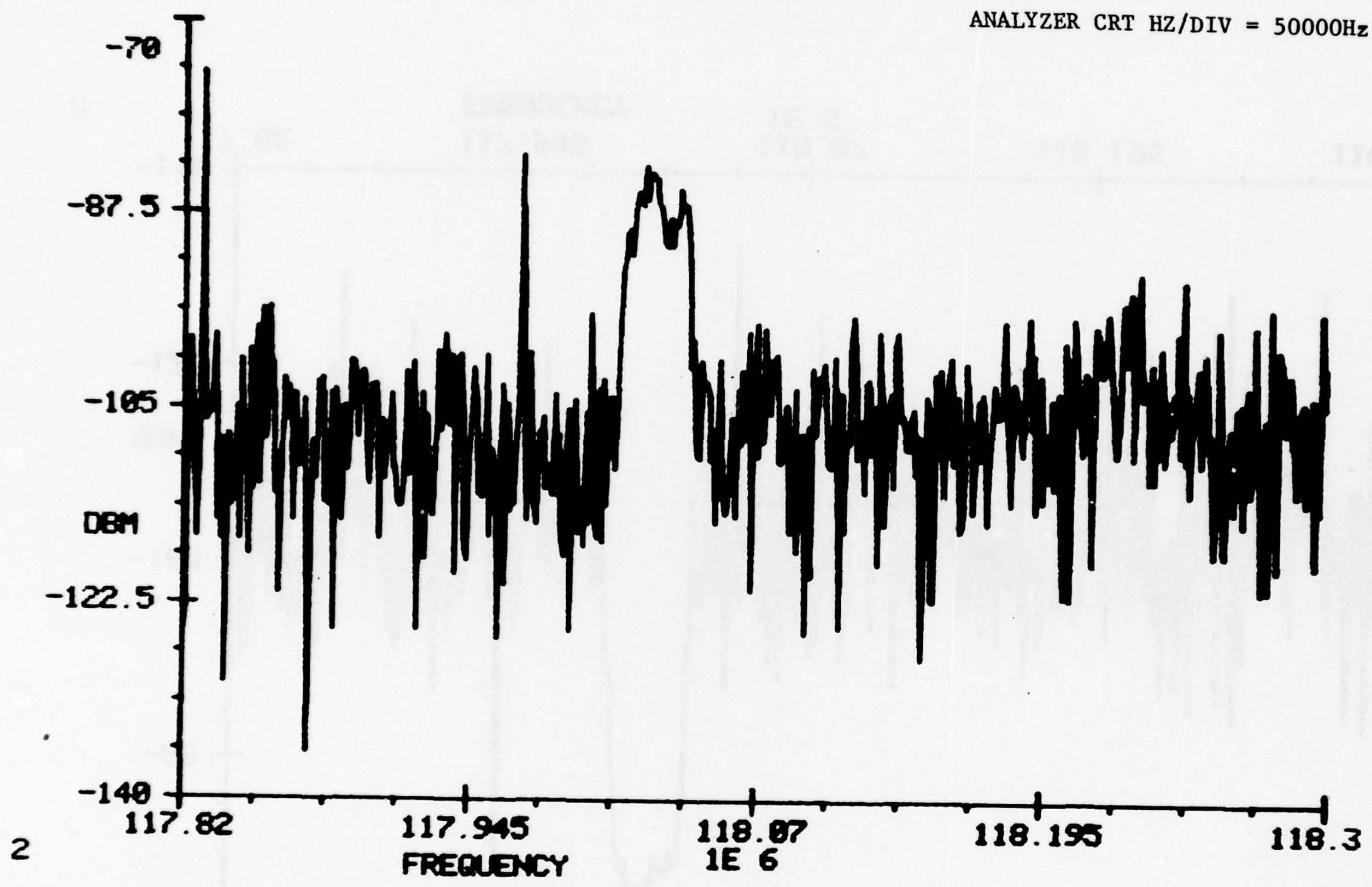


FIGURE 17. ATLANTIC CITY IMAGE NUMBER 2


TRUE
7
8
12
9,13 & 17
14
10
11
5
6
SUSQUEHANNA
RIVER
DAUPHIN CO.

FIGURE 18. FLIGHT GRID OF HARRISBURG, PA

2

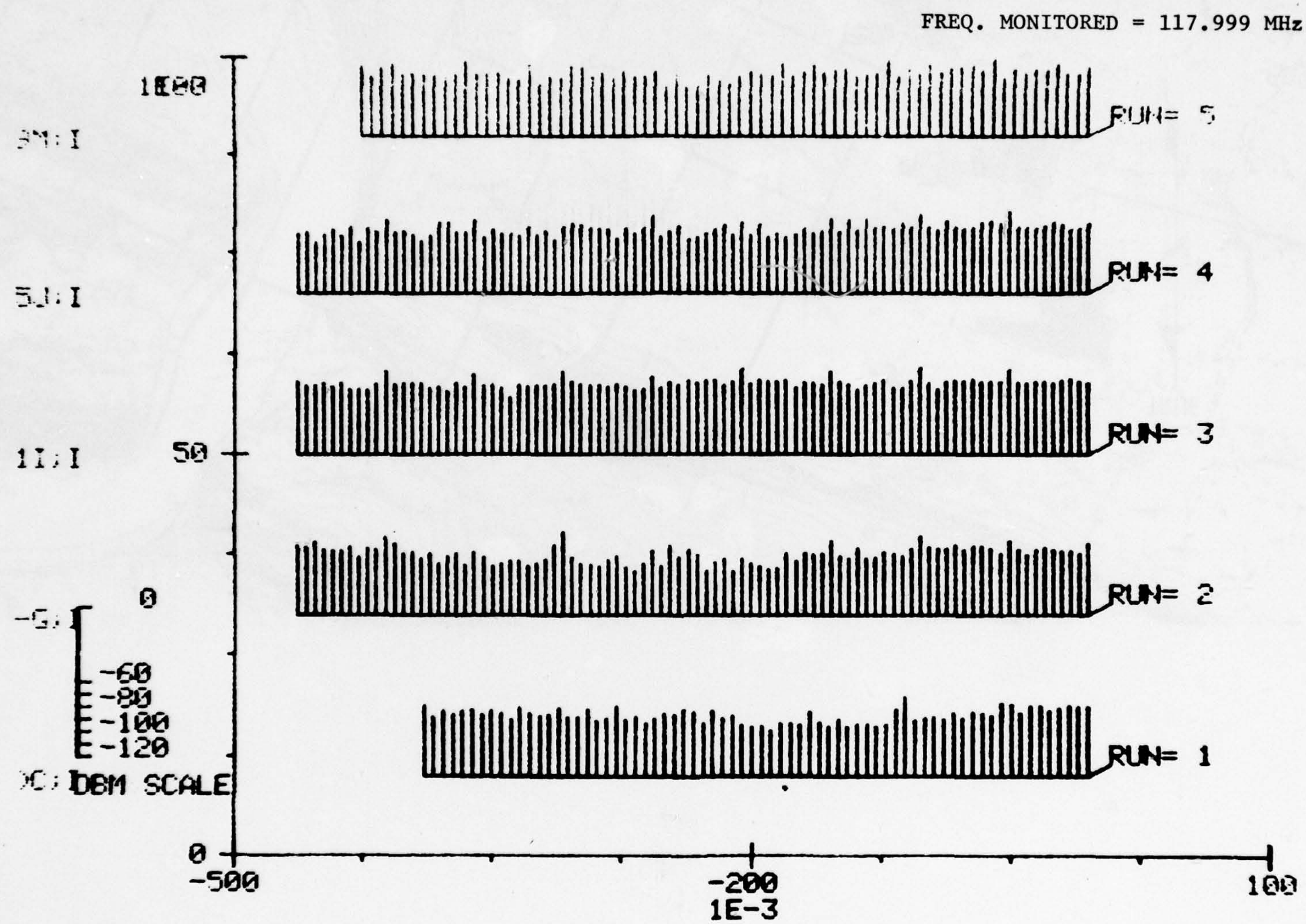


FIGURE 19. HARRISBURG RUNS 1 THROUGH 5 AT 1,500 FT

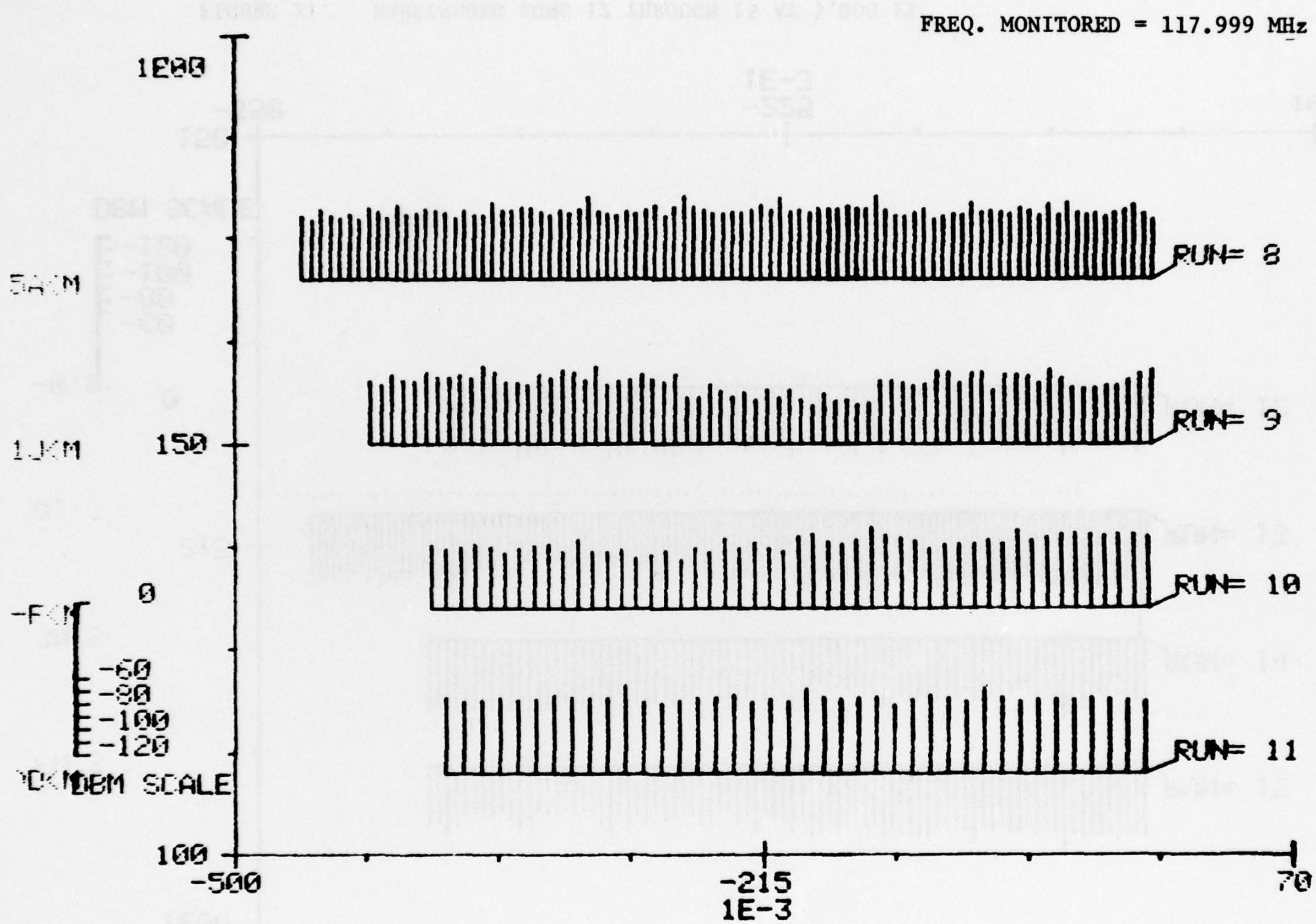


FIGURE 20. HARRISBURG RUNS 8 THROUGH 11 AT 1,500 FT

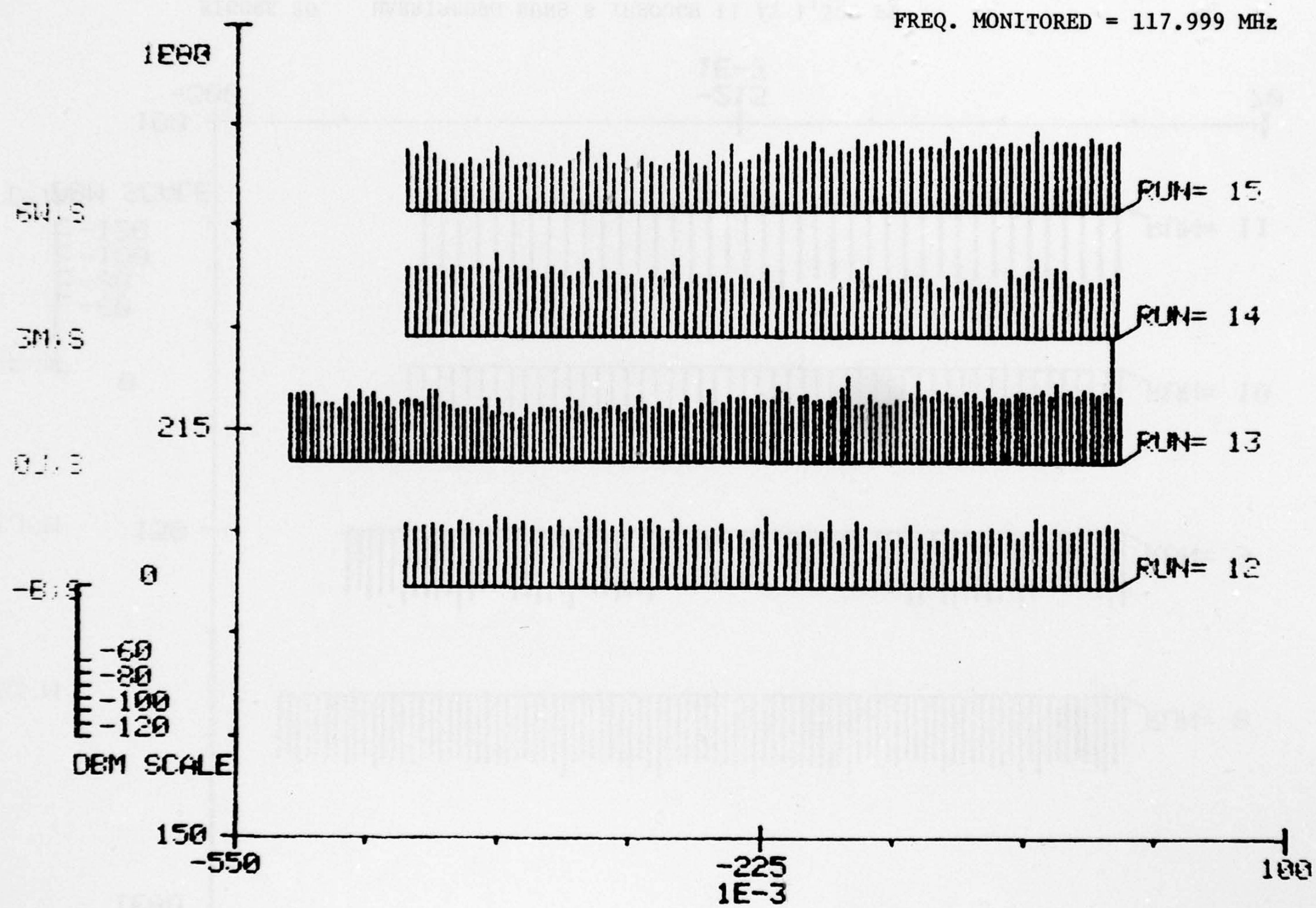


FIGURE 21. HARRISBURG RUNS 12 THROUGH 15 AT 5,000 FT

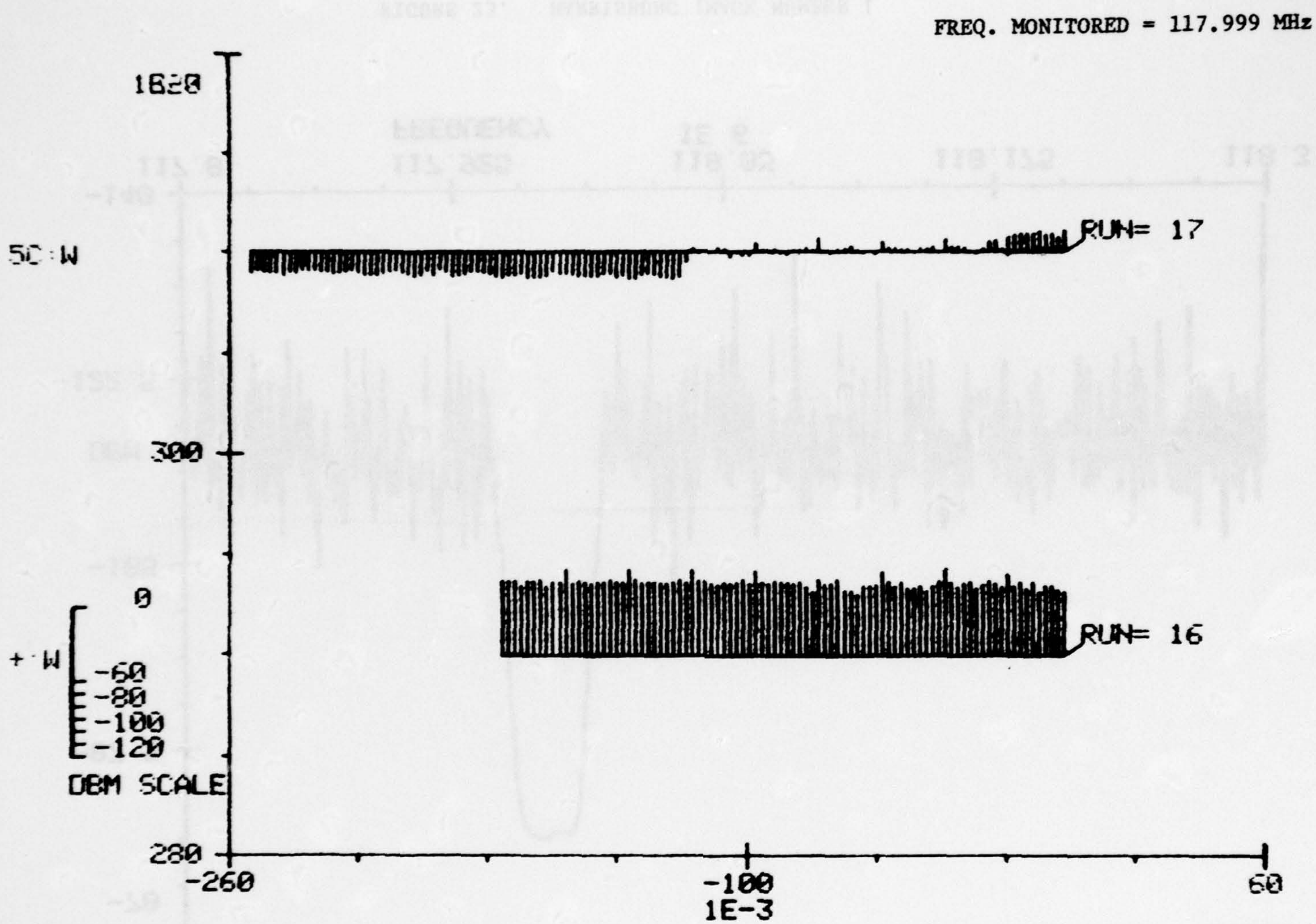


FIGURE 22. HARRISBURG RUNS 16 AND 17 AT 10,000 FT

ANALYZER CRT HZ/DIV - 50000Hz

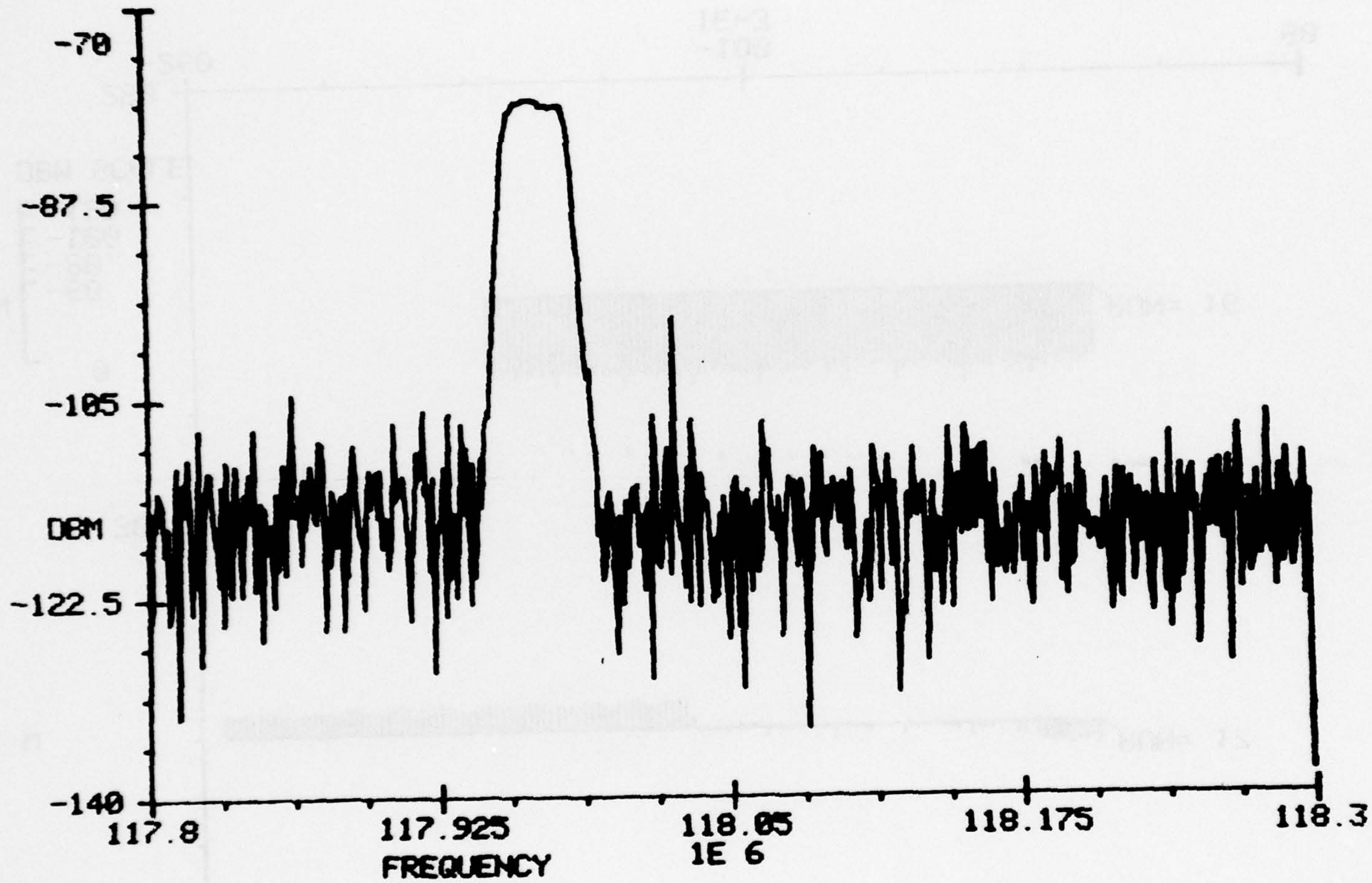


FIGURE 23. HARRISBURG IMAGE NUMBER 1

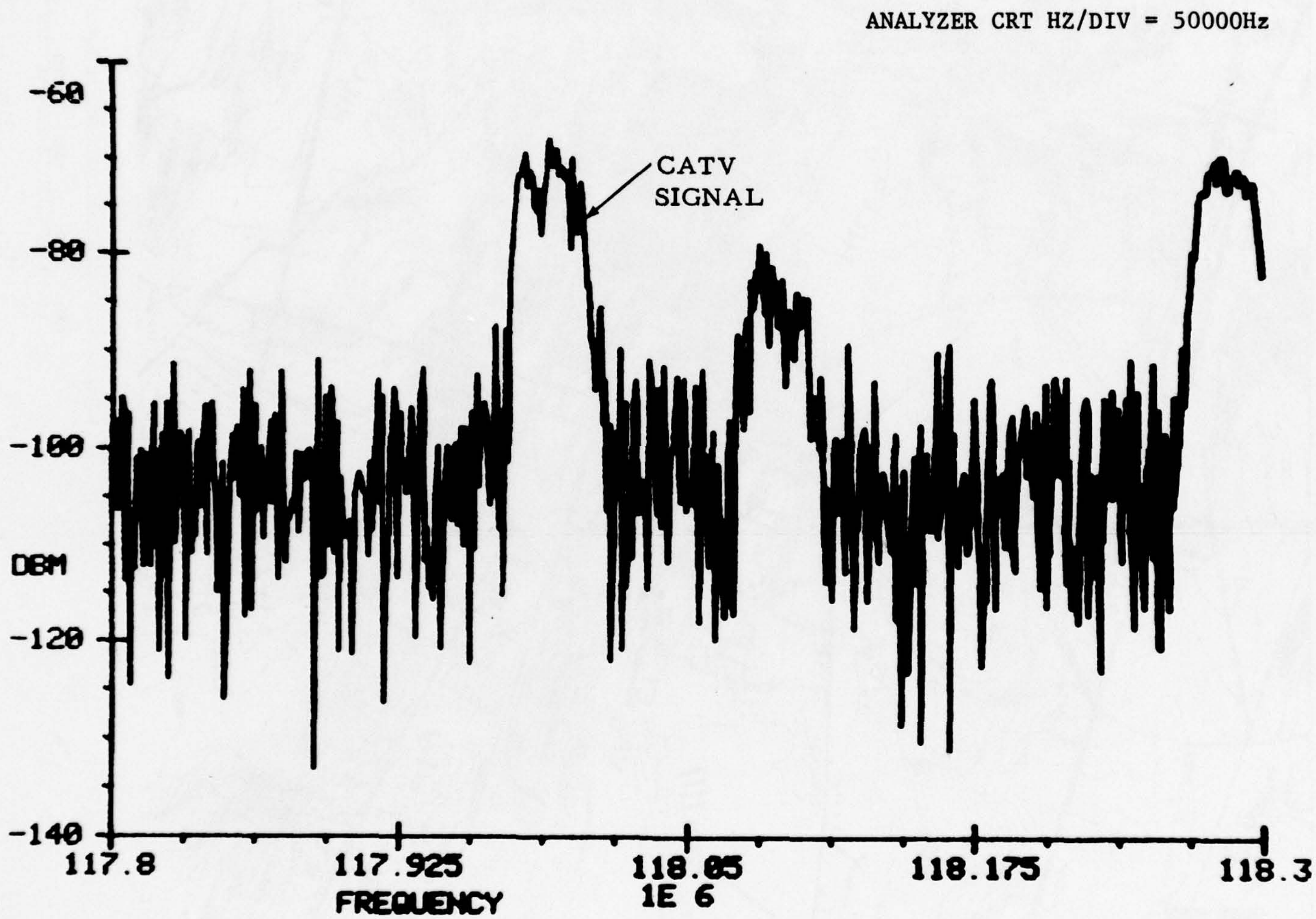


FIGURE 24. HARRISBURG IMAGE NUMBER 2

61

FIGURE 25. FLIGHT GRID OF COATESVILLE, PA

79-9

IGHT GRID OF COATESVILLE, PA

2

1 & 11
2 & 13
3 & 10
7
6 & 9
5 & 12
TRUE
N
BM 638
Paramount
Run
Fountain Head Country Club
WESTERN
MARYLAND
PENN CENTRAL
Hamilton
Radio Tower (WJEJ)
County Home
Point
Reservoir Park
Pangborn Park
County Fairgrounds
Security
Piddlesburg
620
600
580
560
540

FIGURE 26. FLIGHT GRID OF HAGERSTOWN, MD

2

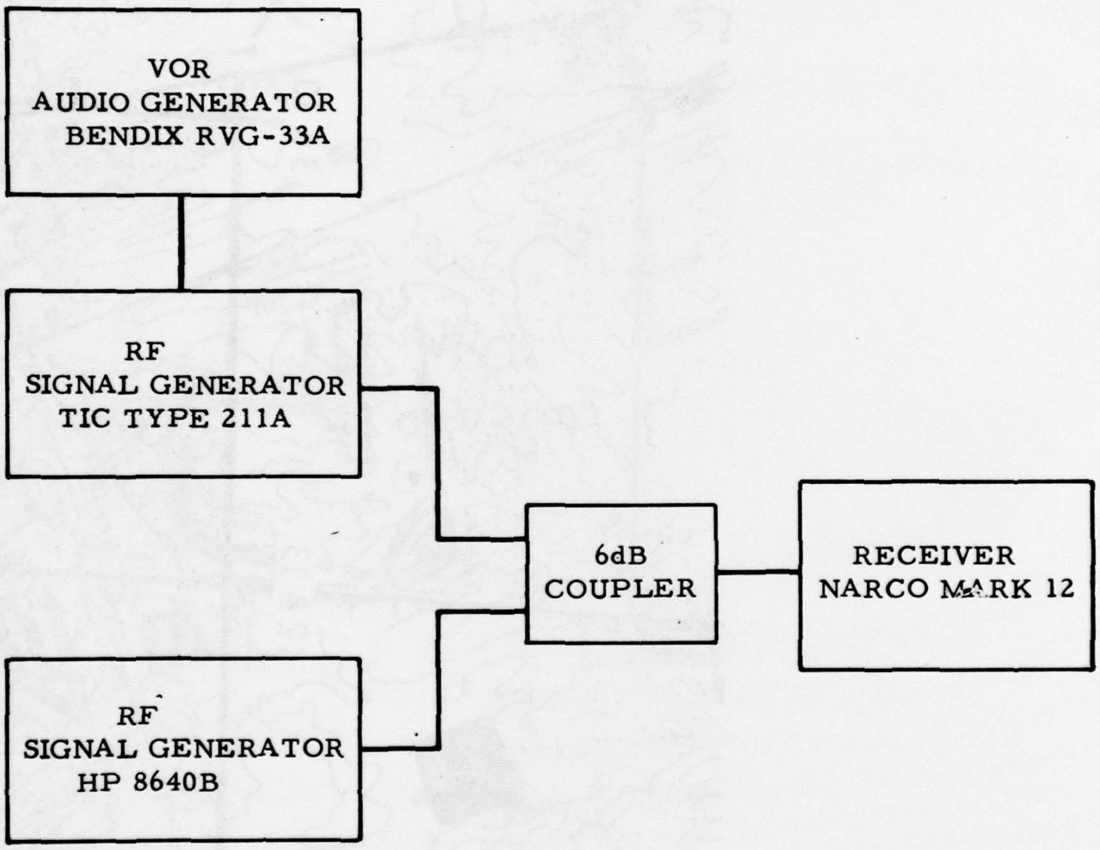


FIGURE 27. EQUIPMENT CONFIGURATION FOR SIMULATED VOR SIGNALS

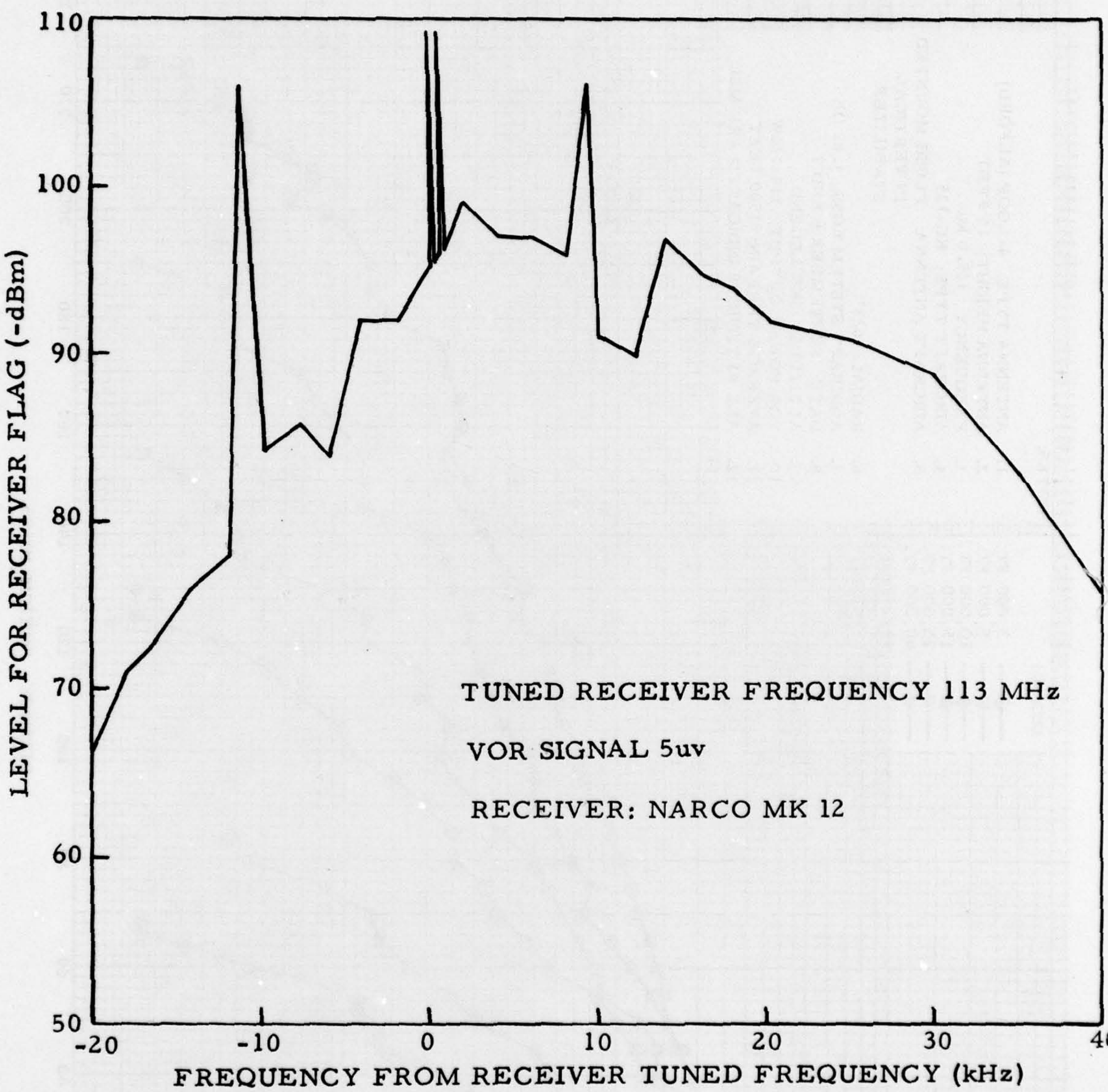


FIGURE 28. VOR INTERFERENCE SIGNALS

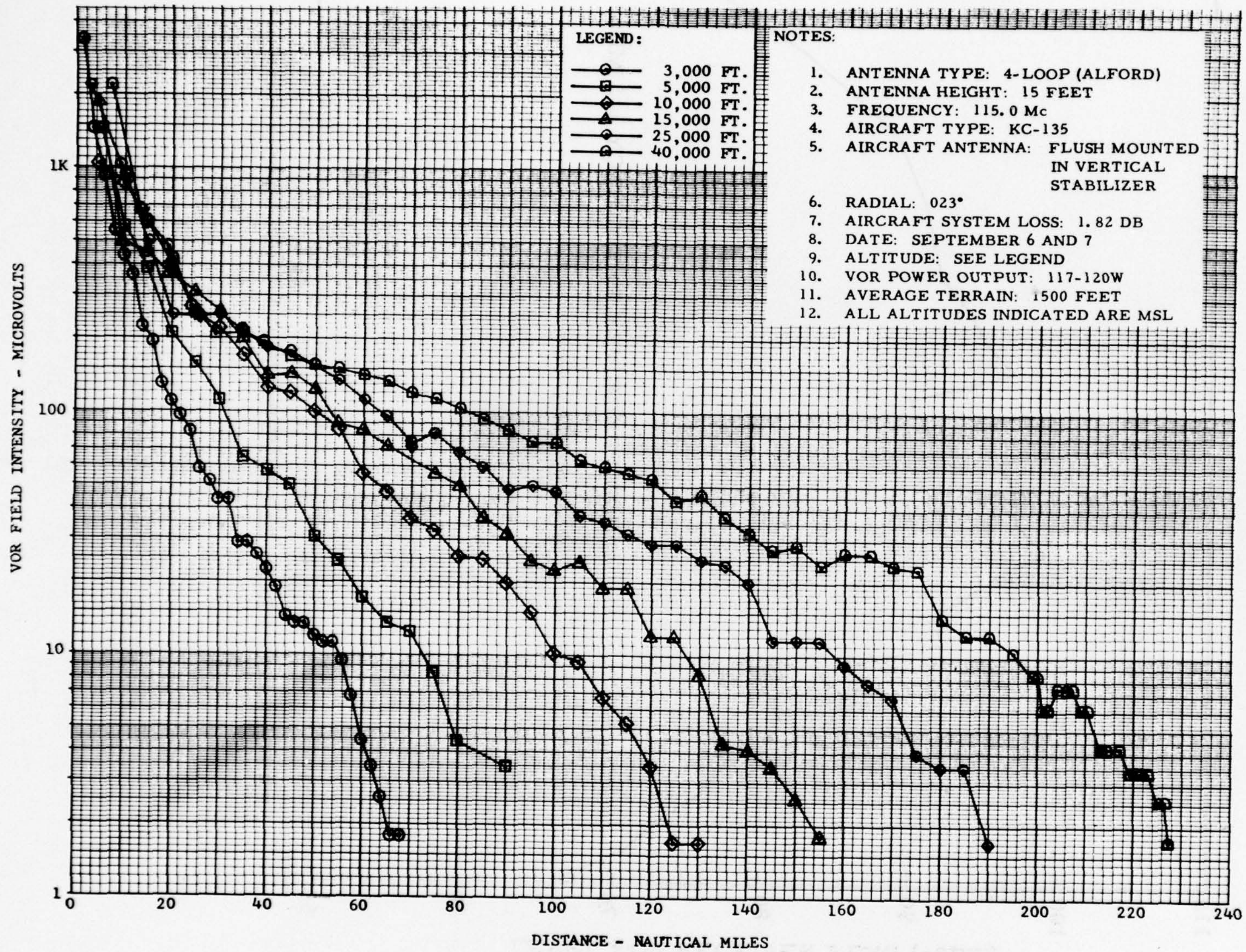


FIGURE 29. COMPOSITE VOR RELATIVE FIELD INTENSITY